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PRELIMINARY EVALUATIONS OF THE PROPOSED REGULATION 308 MODELLING PACKAGE

Report No 87-240-K

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ABSTRACT

A new regulation 308 modelling package has been proposed by the Ontario Ministry of the Environment. The modelling package has been available to industry for evaluation and their feedback since November 1985. This report summarizes the preliminary evaluations of the proposed regulation carried out by the Environmental Science Section, Research Division.

job	file	date	report no.
35-136-591	837.221	October 2, 1987	87-240-K

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EXECUTIVE SUMMARY

PRELIMINARY EVALUATIONS OF THE PROPOSED REGULATION 308 MODELLING PACKAGE

G.C. Edwards and S.C. Wright
Environmental Science Section

The proposed MOE regulation 308 modelling package is composed of several models. The model to be used depends on site and meteorological conditions. The Environmental Science Section (ESS) Research Division, has over the past year obtained these models and undertaken their evaluation with a focus towards identifying inconsistencies, poor parameterizations and difficulties which may be encountered in operational use of the new models to obtain certificates of approval. In the short term, work is needed to obtain sufficient experience with the new models to provide meaningful industry input while the regulations are still in draft form. In the longer term the Corporation will need to develop the capability to work with the new regulation and identify areas of model improvement which will lead to more realistic regulations.

To implement and use the new modelling group is a much more involved and complex process when compared to the procedure presently prescribed by the MOE for air quality approvals. This report describes briefly the course of the ESS model evaluation work program and our experience with the models to date. The report shows the new models to be approximately three times more restrictive than the present regulation model. Preliminary sensitivity tests show the models to be particularly sensitive to the inputs; stack exit temperature, stack exit velocity, wind speed and cloud cover. The model evaluations have also shown most of Ontario Hydro sources would be classified such that region multisource modelling will be required to obtain Certificates of Approval. This protocol is complex and expensive involving compilation or collection of extensive meteorological and source input data sets.

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Future work on the model evaluation will involve extended sensitivity studies, comparison of model predictions with observational data and identification of further work which will benefit the Corporation in using these models to obtain Certificates of Approval.

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To

MR. D.K.A. GILLIES
Manager - Environmental Protection
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PRELIMINARY EVALUATIONS OF THE PROPOSED REGULATION 308 MODELLING PACKAGE

1.0 INTRODUCTION

A new regulation 308 modelling package has been proposed by the Ontario Ministry of the Environment (MOE, 1985). Over the past 18 months, the Environmental Science Section (ESS), funded by EPD, ESA and RMEP, have: (i) acquired these models, (ii) distributed them to interested groups in the Corporation, and (iii) critically assessed any difficulties associated with the application of the models. It is important that the Corporation consider the impact of the proposed models now because only a very brief 120 day period will be available for industry to comment on the yet to be released MOE Green paper on this subject.

When assessing a modelling package, it is important to identify the policy questions affected. Some areas the proposed models will affect are:

(a) permitting of new sources,

(b) permitting of retrofits, and improvements to existing sources,

(c) assessment of emission control options,

(d) assessment of the cost-effectiveness of competing options (eg, air quality monitoring or development of site specific data bases and models), and

(e) assessment of the impact of replacing present models with the proposed ones, in operational use.

These policy questions are the basis for the present model evaluation. Some preliminary results of this evaluation were presented at the joint PCAO/APCA annual conference, held April 5-7, 1987, in Toronto. The purpose of this interim report is to review our experience with the models to date. This will be done

by first providing the necessary background information on the models and then summarizing what was presented at the PCAO/APCA conference, along with results from our further efforts since then. The course of the work for the remainder of 1987 and recommendations for the 1988 budget year will also be presented.

2.0 BACKGROUND

The proposed MOE Regulation 308 modelling package includes three computer programs for modelling dispersion. They are:

(i) the Worst Case Meteorological (WCM) model - for predicting the maximum concentration per unit emission and the downwind distance at which this concentration occurs;

(ii) the Gas model - for estimating concentrations using a given set of source and meteorological conditions which are routinely encountered (Table 1); and

(iii) the Lakeshore model - for estimating concentrations for releases near a lakeshore, during on-shore flow.

The modelling methods used in the proposed MOE Regulation 308 package contrast sharply with those in the current package. In putting together the new package, the MOE reviewed the most recent scientific literature and adopted models suitable for regulatory applications. Table 1 summarizes the techniques that were selected to satisfy various meteorological conditions and site situations which are routinely encountered.

To date, the ESS has provided Design and Development Division - Generation and Technical and Training Services Division with the proposed models converted to run on an IBM-PC compatible microcomputer along with a user guide and sample runs. Updates to the models are made and supplied to the users in these Divisions as they become available from the MOE.

As it stands, a proponent seeking to obtain a permit for a facility would follow a procedure similar to that outlined below:

1. Determine if the source qualifies as a small source (tentatively identified as a source which produces a maximum ground-level concentration which is less than 30% of the short-term standard for the pollutant(s); eg, for SO_2 this would be 30% of 0.25 ppm hourly = 0.075). This is determined by running the Regulation 308 Worst Case models for the source in isolation. The source emissions would have to reflect best practicable control technology as a first requirement. A small source would then have no further requirements for modelling or evaluation beyond this initial step. It is not clear whether multiple sources within a plant must be combined for the purposes of this exercise.

Table 1

Short Range Modelling Methods for Average Air Concentrations from Continuously Emitting Sources

Meteorological Conditions	Simple Situations			Special Situations		
	Near Surface	Elevated	Very Tall Stacks	Lakeshore Setting	Complex Terrain	Building Wakes
Convective	Surface		Convective Scaling	Fumigation model	Case by Case Consideration (may require physical modelling)	Wake re-circulation to ground and enhanced dispersion based on building dimensions
Neutral	Similarity	Revised	Gaussian			
Stable	Modelling					

2. For a source which does not meet the small source criterion, the requirement is to model all sources which have a significant contribution within the radius of influence of the proposed source (this will probably be taken as any source whose radius of influence intercepts the radius of influence of the proponent's source.) No mechanism has been defined as yet to provide source information on plants to be modelled.

3. The radius of influence is defined as the distance at which the proposed source would contribute more than 5% of the ground level concentration standard. This would be determined by use of the WCM model to calculate maximum concentrations at increasing distances from the source. The calculation of this number is not trivial as MOE have not provided the necessary modified WCM for this calculation.

4. The worst case background influx is to be determined by long-term monitoring at the site. The Ministry would need to be consulted to determine the monitoring protocol.

5. For modelling a situation with multiple distributed sources, a grid-point calculating procedure must be adopted, and the worst case concentration must be determined over a representative set of meteorological conditions. The Ministry will specify the maximum grid size to be used for this modelling, however they will not provide a multi-source version of the model code. This must be developed by the proponent.

6. The proponent must assemble meteorological data for the exercise and demonstrate that they represent a typical modelling data set which would correctly predict the maximum concentration potential of the source. The Ministry will provide raw meteorological data from their computer database if this is required.

7. For shoreline sites, the Lakeshore model must be used whenever the flow is on-shore and convective conditions are diagnosed. Within the Lakeshore model, the height of the thermally induced boundary layer (H) is calculated as a function of the distance from the shoreline (x) and a weather-dependent coefficient (A) by $H = Ax^{1/2}$. The A parameter is to be selected over a range of values from 1.5 to 5.0). If a stack does not protrude into the overlying stable layer then the convective model is used for the hour.

8. The model will be set up to accept both a 10 m and stack level wind (it doesn't at the moment.) The 10 m wind will be used to derive the friction velocity u_*, while the stack level wind will be used for the dispersion component. It is not necessary that the two levels of wind be measured at the same location. No interpolation in the vertical is permissible; therefore sites with 10 m level wind only, will use this wind for both calculations.

9. For sources influenced by buildings, the building dimensions must be calculated for each wind direction. Plume impingement on structures is to be calculated for various levels on the structure.

As can be appreciated from the protocol outlined here, the amount of effort required to obtain an approval with the proposed modelling package is substantially greater than with the present regulation. Use of the proposed regulation for obtaining Certificates of Approval, in the case of large sources, will require experienced personnel.

3.0 RESULTS OF MODEL EVALUATIONS

In order to address those issues outlined in the introduction, the approach taken to evaluate the proposed modelling package has been as follows:

(i) Carry out comparisons between the present Regulation 308 model and the proposed worst case model.

(ii) Carry out sensitivity studies on the proposed modelling package.

(iii) Compare observed data and results calculated with the new models.

The following sections contain a summary of our experience with the models to date. Appendix A contains a copy of the PCAO/APCA presentation. Appendix B contains information presented by Concord Scientific Corporation and the MEP Company at the same conference.

3.1 Comparison of Current and Proposed Models

A comparison between the present Regulation 308 model and the proposed Worst Case Model (WCM) was undertaken. It is the WCM which will be used to initially assess whether or not a source would meet the air quality standard, and its status, either small or large. An important question to consider in this comparison is how much more or less restrictive the new model is. To address this question station design data for Lakeview, Lambton and Nanticoke were used as input to both the present and proposed models. Unit emissions were used in this comparison. The results are displayed in Figure 1.

The new model is approximately three times more restrictive than the present model, in all cases. This means nothing to the status quo operation of Ontario Hydro facilities. However, if revisions are undertaken requiring relicensing (eg, Lambton TGS), the proposed models will supplant the old model in operational applications. Compliance will be somewhat more involved than in the past.

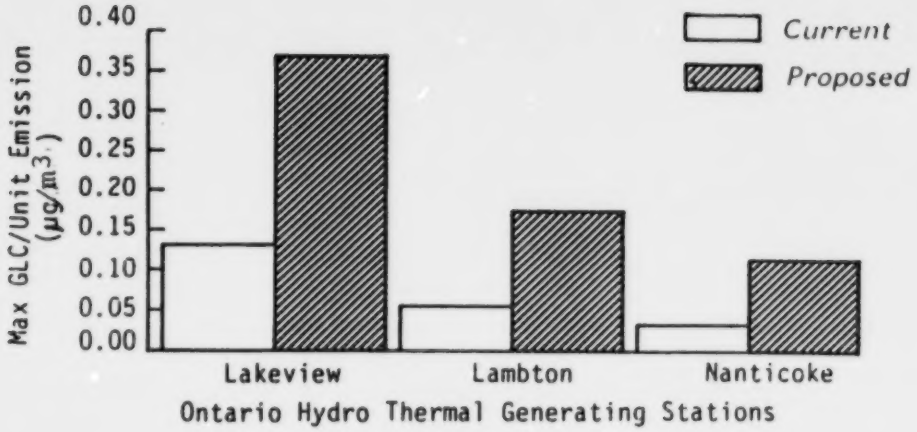

FIGURE 1
COMPARISON OF CURRENT AND PROPOSED MODELS

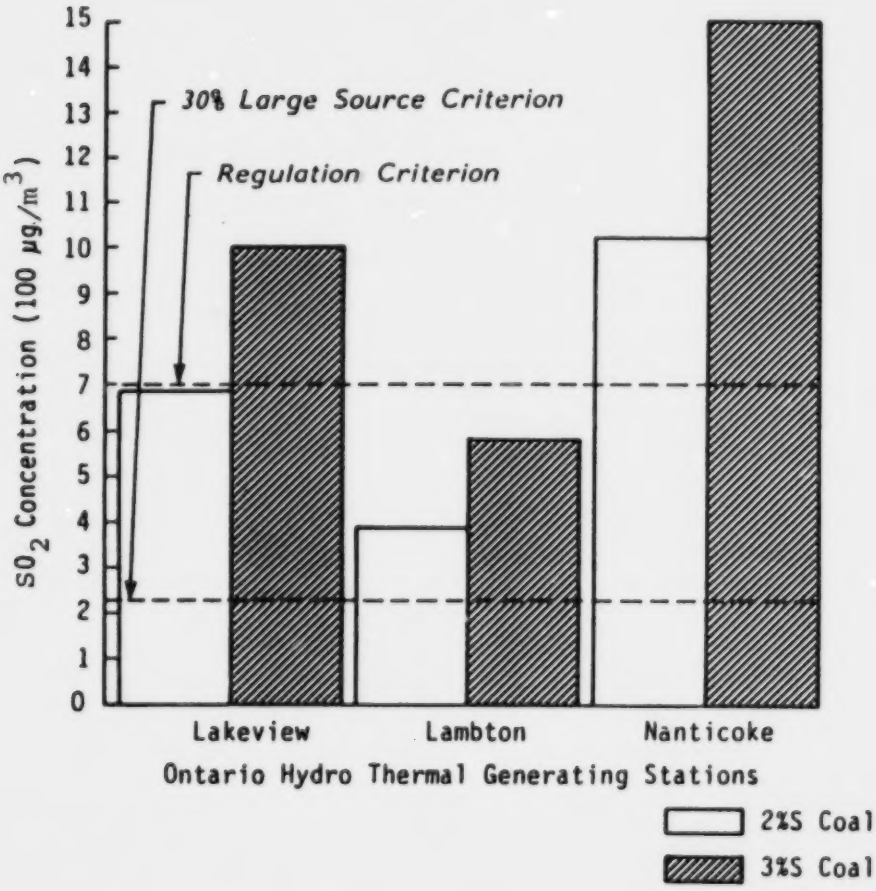

FIGURE 2
PROPOSED REGULATION 308 WORST CASE MET MODEL
RESULTS FOR 90% EFFECTIVE WET SCRUBBERS

To further illustrate this point consider the case presented by T.S. Wong in a memo to W.M. Patterson, March 1987 shown by Figure 2.

Here 10% of the SO_2 emission of the three stations under full load is considered for both 2% and 3% sulfur coal under a wet scrubbing scenario where flue gas exit temperature would be reduced to 50°C. If the proposed Regulation 308 applies when scrubber retrofits are undertaken, then the large source modelling protocol outlined earlier would have to be applied to obtain the necessary Certificate of Approval for all three generating stations. In the cases of Lakeview and Nanticoke the proposed wet scrubbing scenario would lead to violation of the hourly SO_2 air quality criterion.

To understand the basic reason why the proposed WCM is more restrictive than the present model some sensitivity studies were carried out. The models are most sensitive to two parameters, stack exit temperature and exit velocity. This is illustrated by Figure 3.

Typical Lakeview operating data were used as source input for these calculations. It can be seen from Figure 3 that as stack exit temperature falls below 95°C and the stack exit velocity below 22 m/s the proposed WCM will predict increasingly higher ground level concentrations (glc). More dramatic increases in glc are seen as exit temperature falls below 65°C and exit velocity below 18 m/s. The models are most sensitive to these parameters because the plume rise equation used in the proposed models is based on Briggs (1984) equation which is more sensitive to these inputs than is the Holland (1953) formulation used in the present model.

3.2 Sensitivity Studies

Under the proposed regulation the proponent will need a representative year of input data to comply with the multi-source modelling protocol. The Ministry will provide a representative year of climatological data. Suitable site-specific data supplied by the applicant will also be accepted by the Ministry. Depending on model sensitivity to a particular parameter it may be beneficial and cost-effective for the applicant to maximize accuracy for a particularly sensitive parameter or consider collecting accurate site-specific data in the case of a sensitive meteorological input. To start to identify sensitive inputs to the modelling package, a Lakeview base case was selected and all inputs varied within limits of error which could reasonably be expected in the input parameter. For example, wind speeds are often not available at this site of interest and it is necessary to obtain data from a nearby routine meteorological station. Winds obtained from the meteorological station could be substantially different from those experienced at the site. Similarly, at the site of interest stack exit temperatures estimated from design data and observed in practice could differ by, say, 20%.

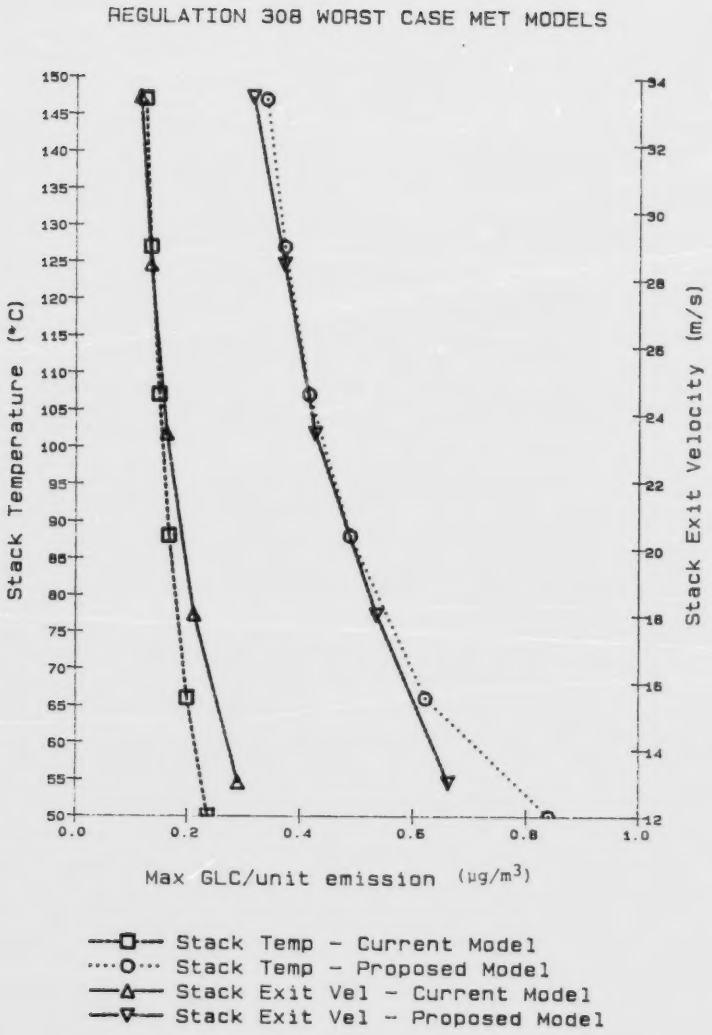
REGULATION 308 WORST CASE MET MODELS
Stack Temperature (°C)
Stack Exit Velocity (m/s)
Max GLC/unit emission (µg/m3)
Stack Temp - Current Model
Stack Temp - Proposed Model
Stack Exit Vel - Current Model
Stack Exit Vel - Proposed Model

FIGURE 3

Sensitivity of Current and Proposed Worst Case Met Models to Stack Exit Temperature and Stack Exit Velocity Inputs

If the models are not particularly sensitive to these parameters then this error will have little effect on the outcome. However, if they are sensitive, then improved accuracy may be needed.

3.2.1 Gas Model

As was shown by Figure 3, the WCM was most sensitive to the stack exit temperature and velocity input parameters. The Gas model also displays sensitivity to these input parameters for the same reason as the WCM. Figure 4 illustrates this sensitivity in the Gas model case.

Two other parameters the Gas model was somewhat sensitive to were wind speed and cloud cover. Figure 5 displays these results. The degree of model sensitivity is not a linear function of parameter value in either case. Cloud cover variations affect results most in the range of 4 to 8 oktas. Wind speed, on the other hand, affects results significantly throughout the range studied.

3.2.2 Lakeshore Model

Figure 6 depicts the physical scenario which the Ministry Lakeshore model simulates.

The Lakeshore model can be thought of as a two-component model. The first component is the rise and spread of the plume in the stable layer until it intersects the boundary layer. The second component is then the dispersion of the plume into the boundary layer from the area of impingement at the top of the boundary layer. If the plume rise is sufficiently high to avoid plume intersection with the boundary layer, the model will predict zero ground level concentrations. On the other hand, if the plume intersects a low boundary layer, the glc's will be higher than if the plume intersects a higher boundary layer. This is because there is more volume for dilution in the latter case. Consequently, the Lakeshore model is not particularly sensitive to those inputs which affect the plume rise component of the model. Instead, it shows greatest sensitivity to the parameters defining the boundary layer component. Figure 7 illustrates this by displaying the glc pattern for variations of the boundary layer height around a base case.

In practice, the Lakeshore model would be applied by varying the boundary layer height parameter A over the range 1.5 to 5 to determine the worst case. Figure 7 shows the model to be sensitive to this parameter, with a marked variation in the calculated glc as A is varied. Significant variation in the location of the maximum glc can also be seen.

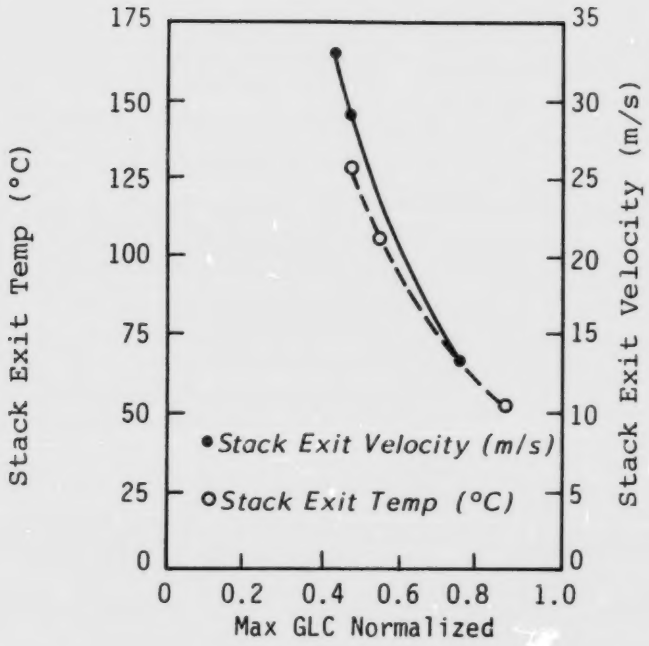

FIGURE 4
GAS MODEL SENSITIVITY TO STACK EXIT TEMPERATURE AND VELOCITY

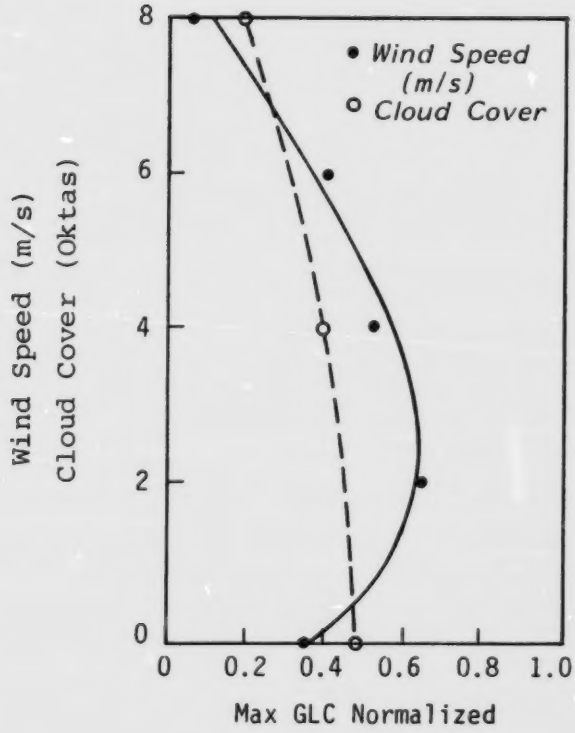

FIGURE 5
SENSITIVITY OF GAS MODEL TO WIND SPEED AND CLOUD COVER INPUTS

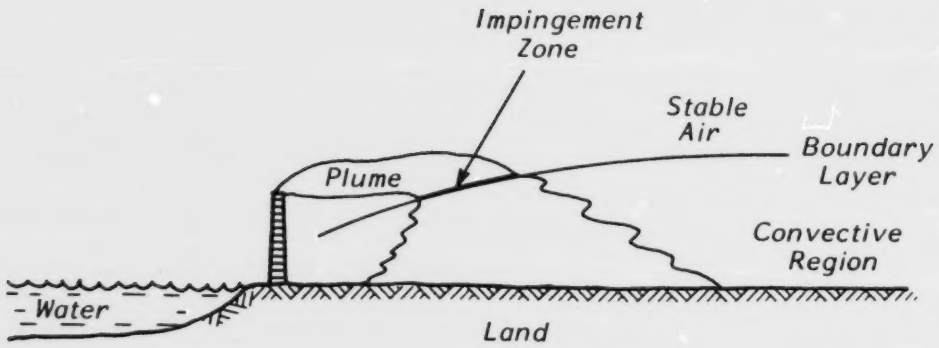
Impingement
Zone
Stable
Air
Boundary
Layer
Plume
Convective
Region
Water
Land

FIGURE 6

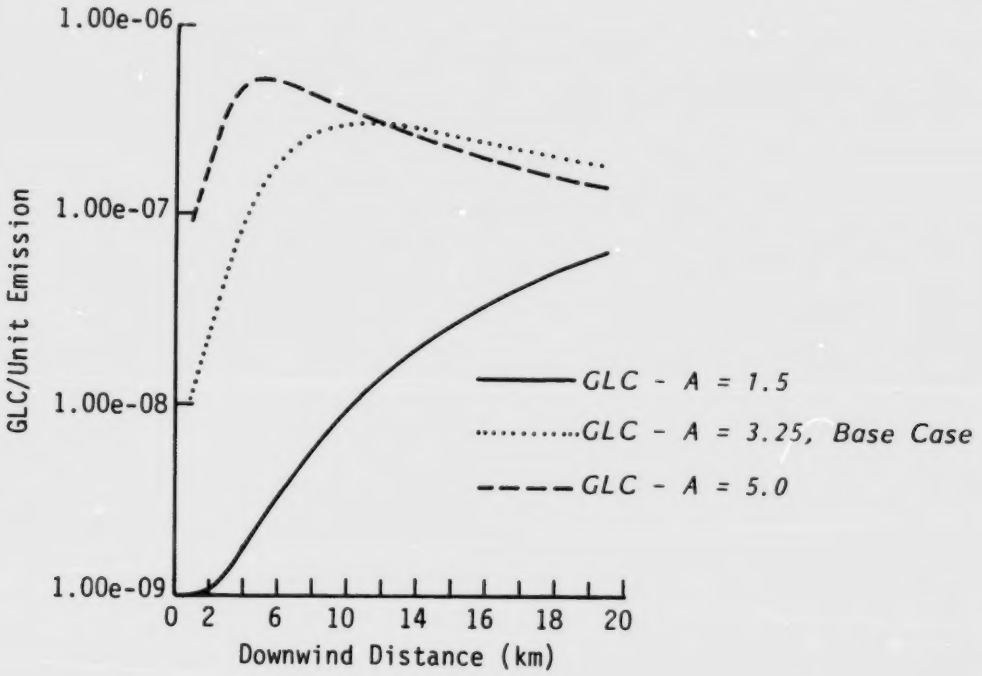

FIGURE 7

VARIATION OF GROUND LEVEL CONCENTRATION AS A FUNCTION OF BOUNDARY LAYER HEIGHT PARAMETER A.

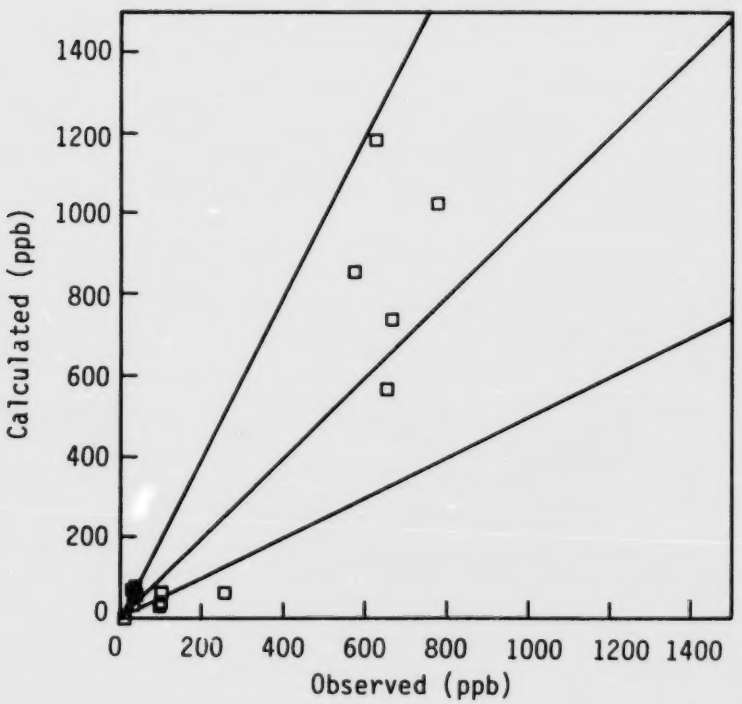

FIGURE 8

COMPARISON OF LAKESHORE MODEL TO OBSERVATIONS COLLECTED FOR LAKEVIEW TGS $r^2 = 0.86$

3.3 Comparison of Model with Observations

The purpose of the comparison of model predictions with appropriate observational data is to determine how well the new models perform and, therefore, how realistic regulation based on these proposed models might be.

Comparison of a model with numerical data is a very difficult task as the data must align in all respects with the assumptions and physical situation upon which the model is based. For example in the case of the Lakeshore model, sufficient data must be available to ensure the physical situation described in Section 3.2.2 is indeed occurring. As well, ground-level concentration data must be available. Models generally predict ensemble average concentrations, which may not be achieved with a time-averaged glc observation. Thus, numerical comparisons may not be very meaningful.

At this time, sufficient data have not been assembled to carry out complete comparisons with the Gas and Lakeshore models. A complete database of observational data appropriate for comparisons with the Gas model has been requested from the US EPA. These data have not been received to date. For the Lakeshore model, Ontario Hydro has some complete data available in-house. Compilation of this data is in progress. Approximately 14 cases of observational data for Lakeview TGS were assembled for a preliminary comparison with the Lakeshore model. Comparisons with observations for the Lakeshore model have been previously carried out by the model's author, P.K. Misra. These comparisons are reported by Misra (1980). Good agreement with observations are shown with the limited amount of data presented by Misra. The results of the present comparison are shown by Figure 8. The best fit linear regression has a slope of 1.36 indicating the model has a tendency to overpredict the glc. However, most observation/calculated comparisons lie within the factor of two criterion for reasonable model performance.

4.0 FUTURE WORK

The work program for the remainder of 1987 will involve following through with the sensitivity studies and comparison of the models to observed data. The latter task will involve obtaining a suitable comparison database for the Gas model from the US EPA. As part of these evaluations, model performance will be assessed for the various facilities Ontario Hydro operates. For example, a

Lakeshore nuclear station (short stack - non-buoyant plume), diesel generators (short stack - buoyant plume), etc.

The focal point for these activities in the short-term has been to obtain sufficient experience with the models to comment, from a position of knowledge, on the technical aspects when the Green paper is issued by the government.

In the longer term, the work program may be twofold; (1) it is evident from the preliminary evaluations that Hydro at some point will need to be involved in multi-source modelling, and (2) in the process of evaluating the modelling package, potential areas of research may be identified which will improve the accuracy of the model parameterizations.

The MOE does not intend to provide a multi-source version of the model code; it will, therefore, be necessary to develop this capability in-house.

The development is envisioned to be two-fold; one, the actual development and testing of a model code, and secondly, the development of the capability to assemble the necessary data and carry out multi-plant analyses. Over the past year, the consulting firm MEP has developed and extensively tested a multi-source model code which it is offering for sale at approximately $2,500. This product could not be developed in-house for this cost. Historically, Ontario Hydro has maintained in-house expertise to carry out the necessary work for Certificates of Approval. It may therefore be cost-effective to purchase the MEP multi-source model and focus in-house efforts on development of the capability to carry out multi-plant simulations.

5.0 CONCLUDING REMARKS

From our experience with the proposed modelling package to date, it is evident that the procedure of attaining Certificates of Approval will be substantially more time consuming in the future. Close interaction with the Ministry during the approval process will be required. The proposed regulation is considerably more restrictive. This should be taken into consideration early in the development stage of facilities requiring licensing. It is

evident that the capability to carry out multi-source modelling will be needed in the future and efforts towards developing this capability should get underway.

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APPENDIX A

ONTARIO HYDRO PRESENTATION AT THE JOINT PCAO/APCA ANNUAL CONFERENCE APRIL 5-7, 1987

EVALUATION OF REGULATION 308 MODELS WITH SITE SPECIFIC DATA

G.C. Edwards
S.C. Wright
D.N. Kirshak
E. Laratta

Ontario Hydro

87-240

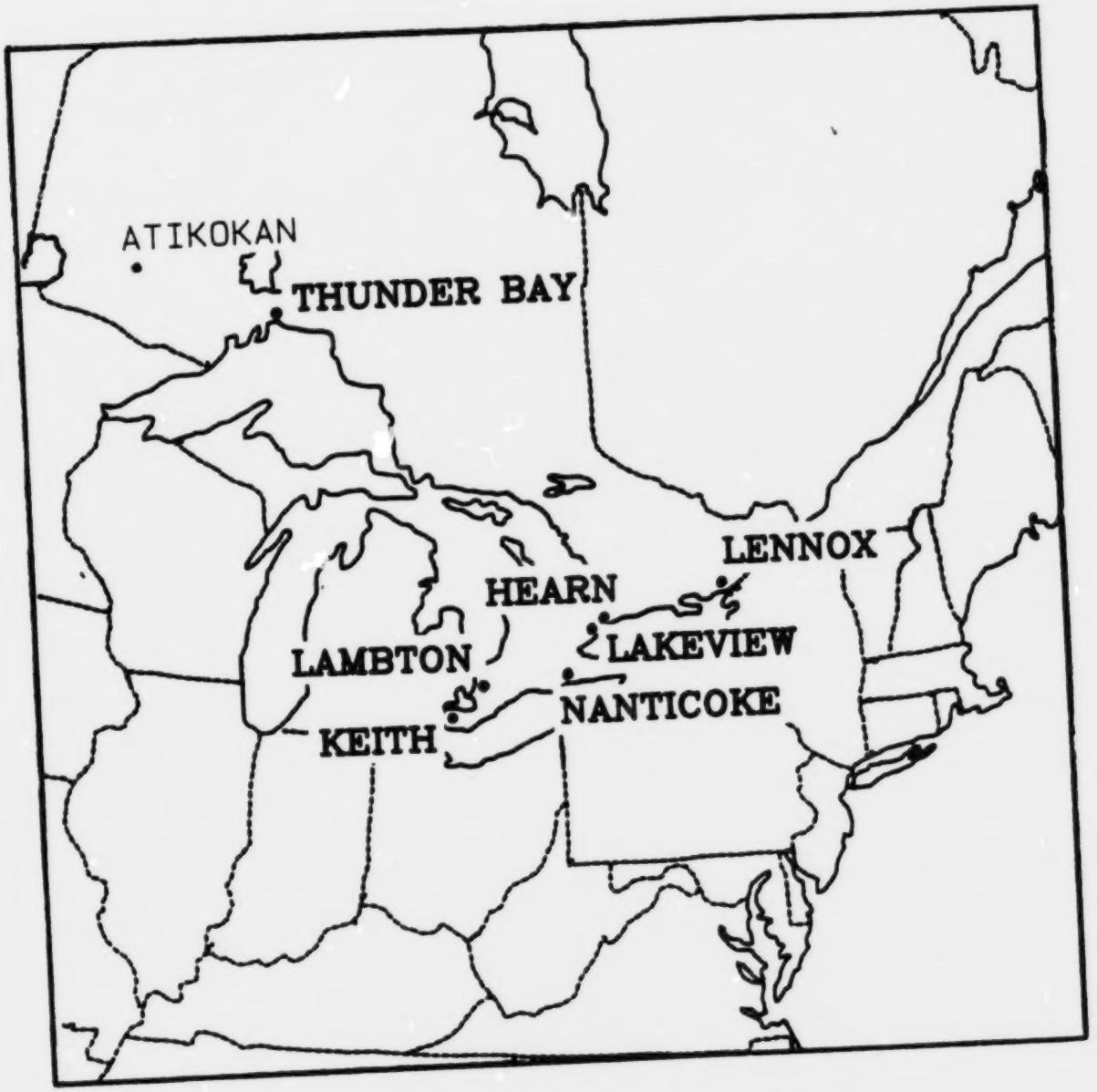
Current/Proposed Worst Case Met Models

SO2 Control Technology (w/wo scrubbers)

Lakeview – Stack Exit Temp 50° C/147° C

Lambton – Stack Exit Temp 50° C/143° C

Nanticoke – Stack Exit Temp 50° C/121° C



ONTARIO HYDRO'S
FOSSIL–FIRED POWER PLANTS

87-240

Table 1

Thermal Generating Station Summary

Station	Location	Capacity (MW)	No. Of Units	Stack Height (m)	Number of Stacks	Stack Configuration
Lakeview	Mississauga	2 400	8	150.3	4	Single Flue
Lambton	Courtwright	2 040	4	167.6	2	Single Flue
Nanticoke	Haldimand-Norfolk	4 040	8	198.1	2	Multi-Flue

Current/Proposed Worst Case Met Models

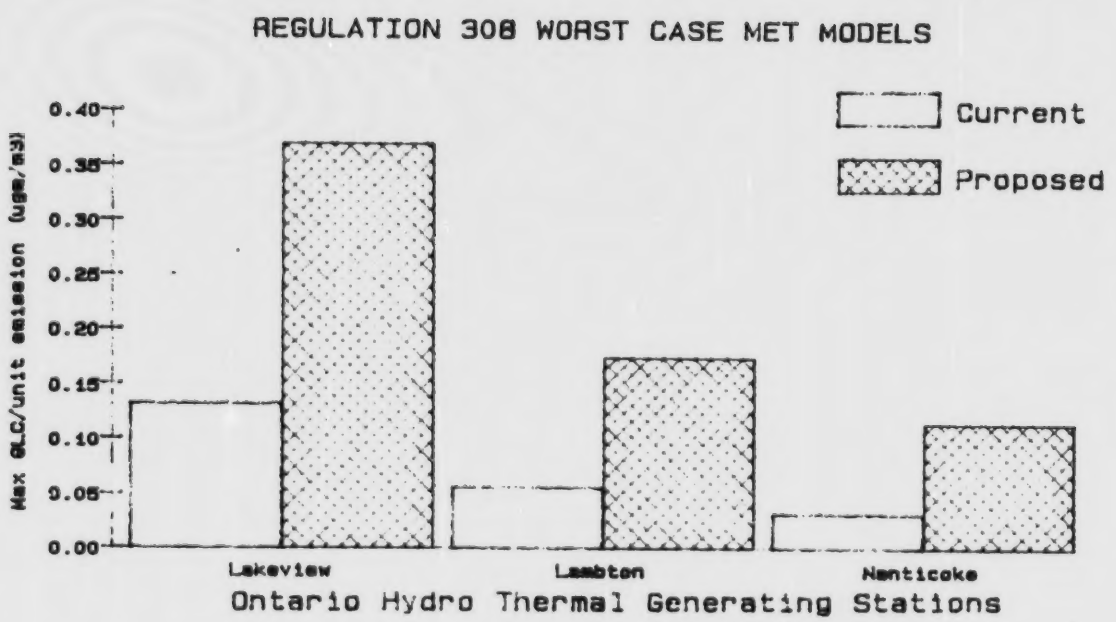
Lakeview Base Case – Sensitivity Analysis

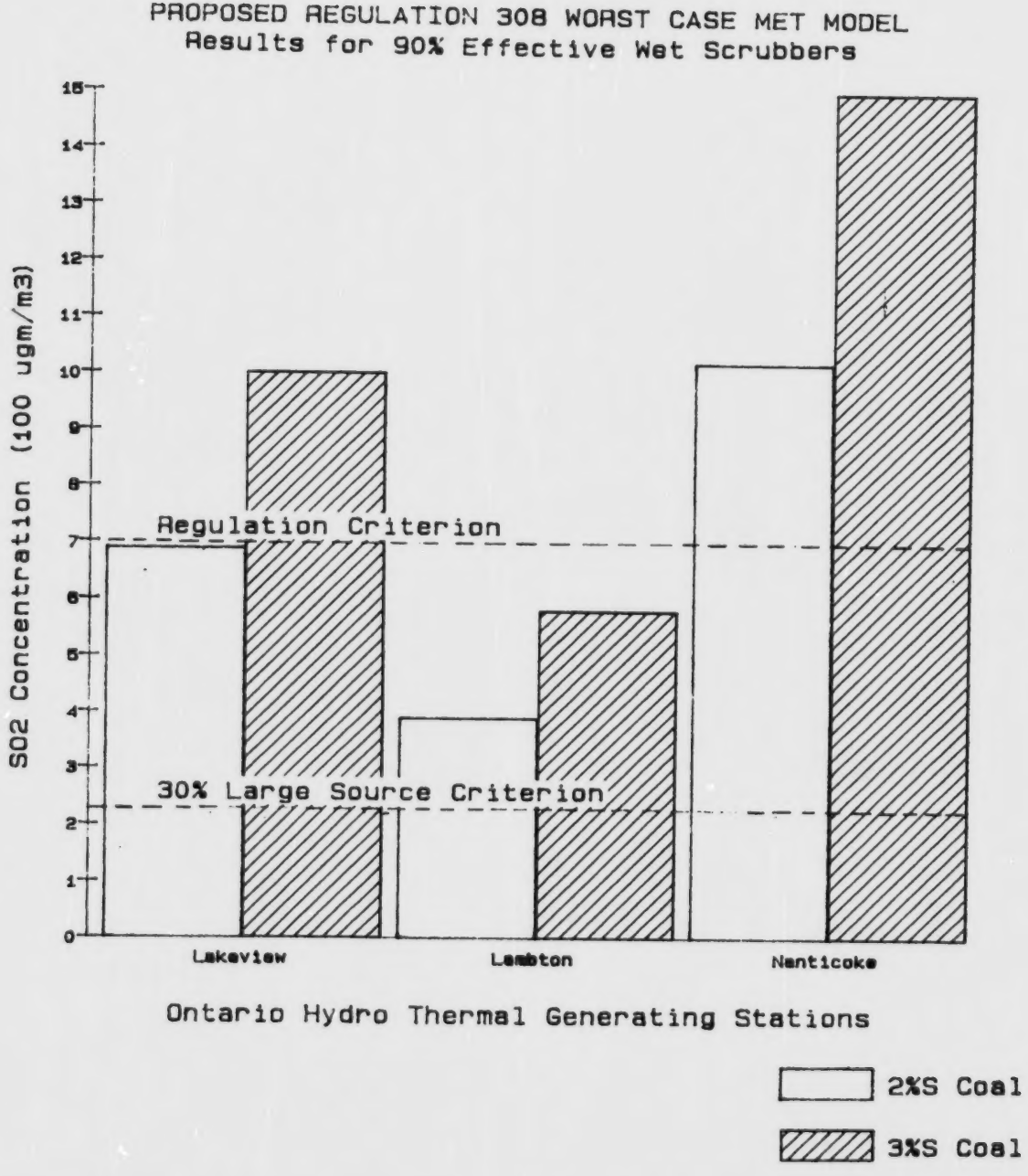
Stack height 150 m

Stack diameter 5.94 m

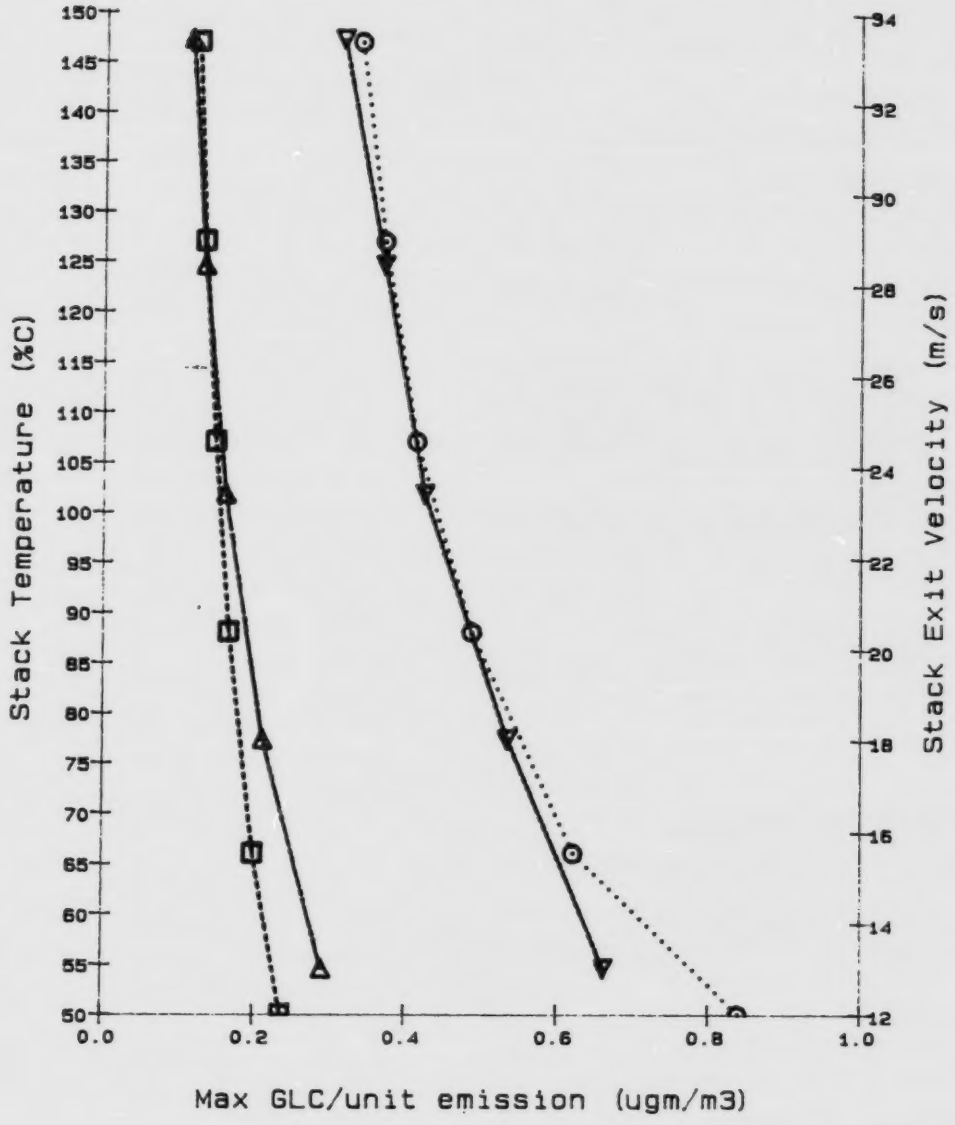
Stack exit temperature 50° C – 150° C

Stack exit velocity 13 m/s – 33.4 m/s


REGULATION 308 WORST CASE MET MODELS
Current
Proposed
Max GLC/unit emission (ug/m3)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Lakeview
Lambton
Nanticoke
Ontario Hydro Thermal Generating Stations


PROPOSED REGULATION 308 WORST CASE MET MODEL
Results for 90% Effective Wet Scrubbers
SO2 Concentration (100 ugm/m3)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Regulation Criterion
30% Large Source Criterion
Lakeview
Lambton
Nanticoke
Ontario Hydro Thermal Generating Stations
2%S Coal
3%S Coal

REGULATION 308 WORST CASE MET MODELS

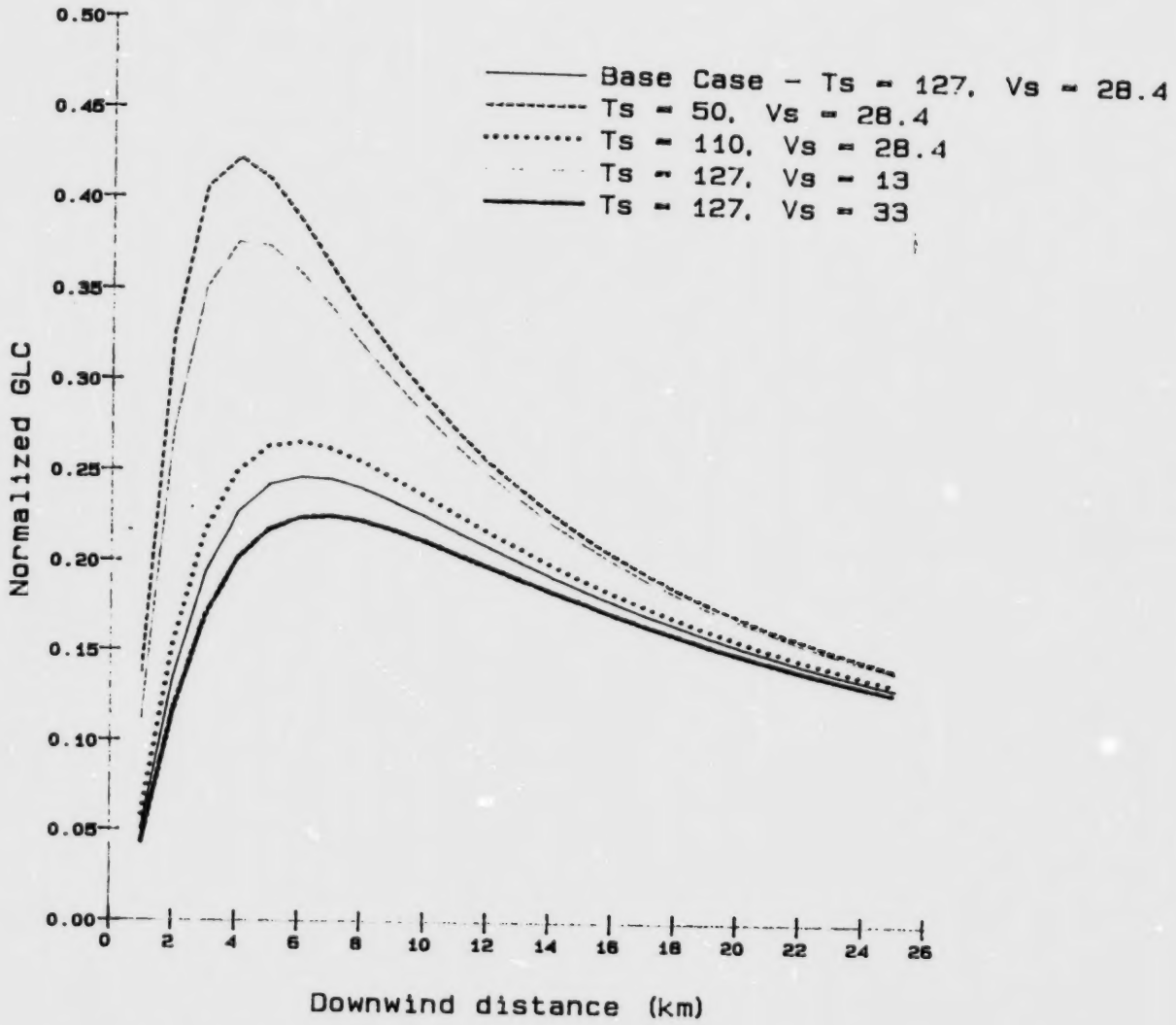


Proposed Gas Model

Lakeview Base Case – Sensitivity Analysis

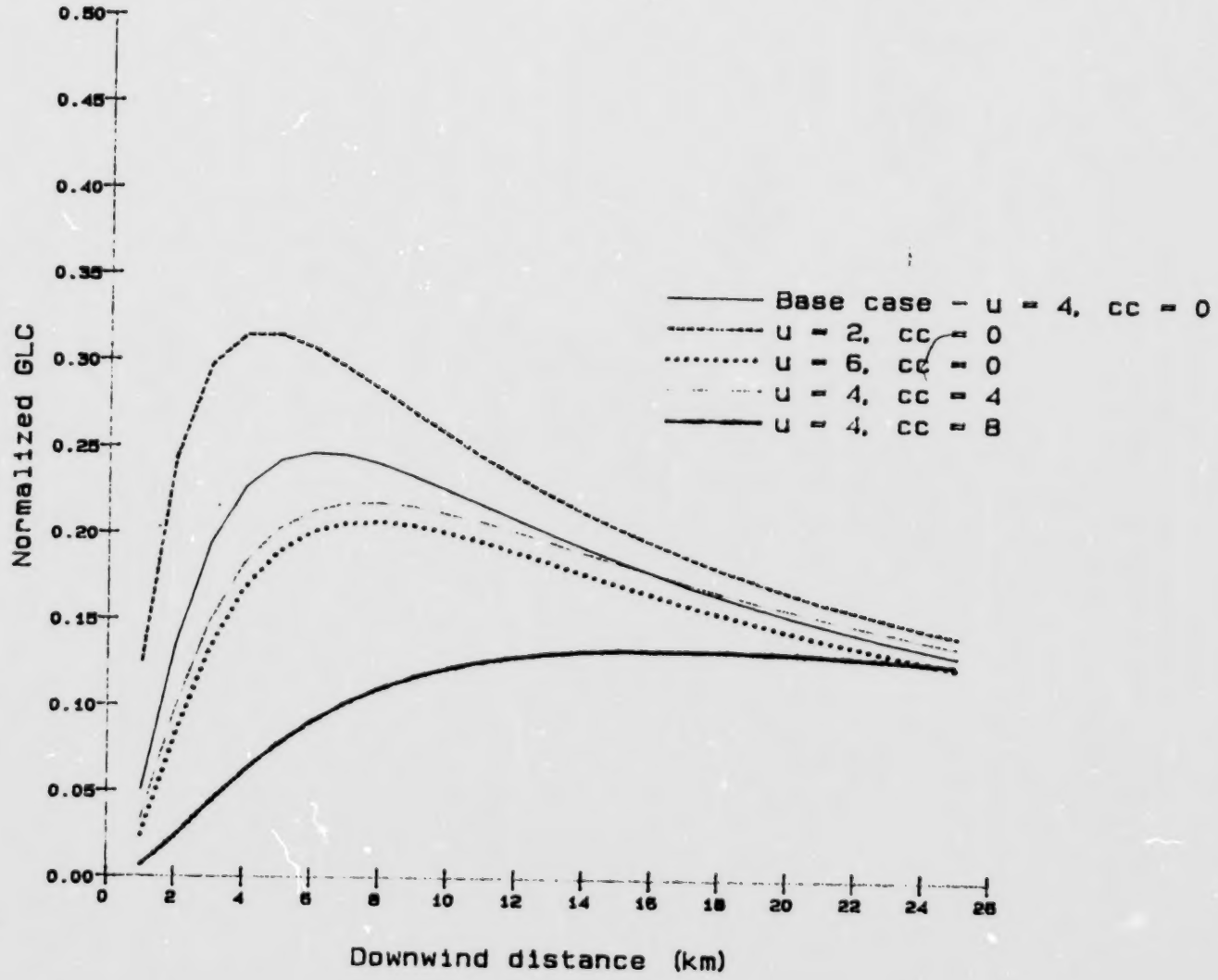
Stack height 150.3 m
Stack diameter 5.94 m
Stack exit temperature 127° C (50° C – 150° C)
Stack exit velocity 28.4 m/s (13, 33.4)
Time of day 12 noon (9 am, 3 pm)
Ambient temperature 20° C (10° C, 30° C)
Wind speed 4 m/s (2 m/s, 6 m/s)
Cloud cover 0 oktas (4, 8)
Mixing height 300 m (750, 1200)

Proposed Gas Model Sensitivity Analysis - Ts, Vs

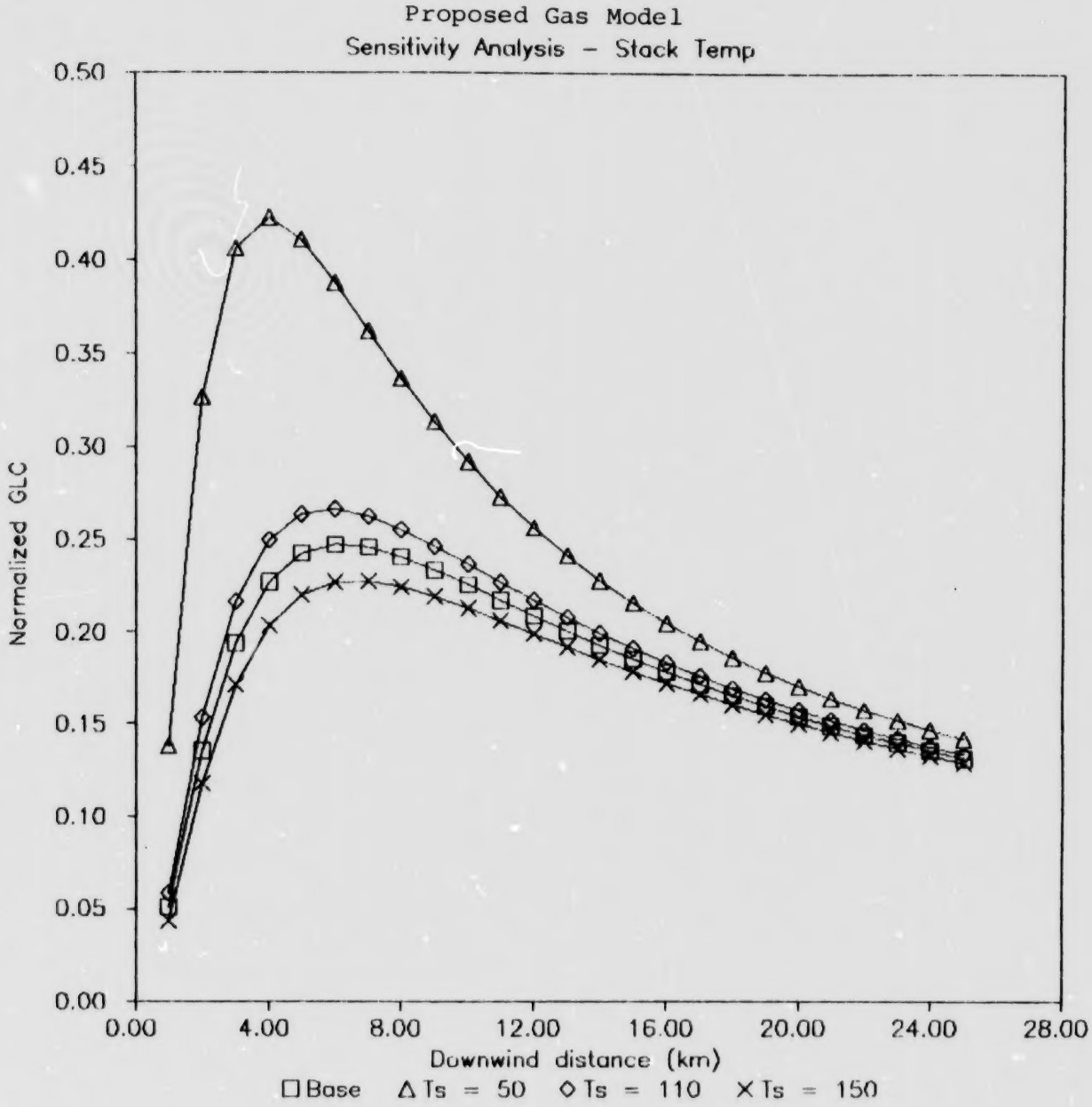


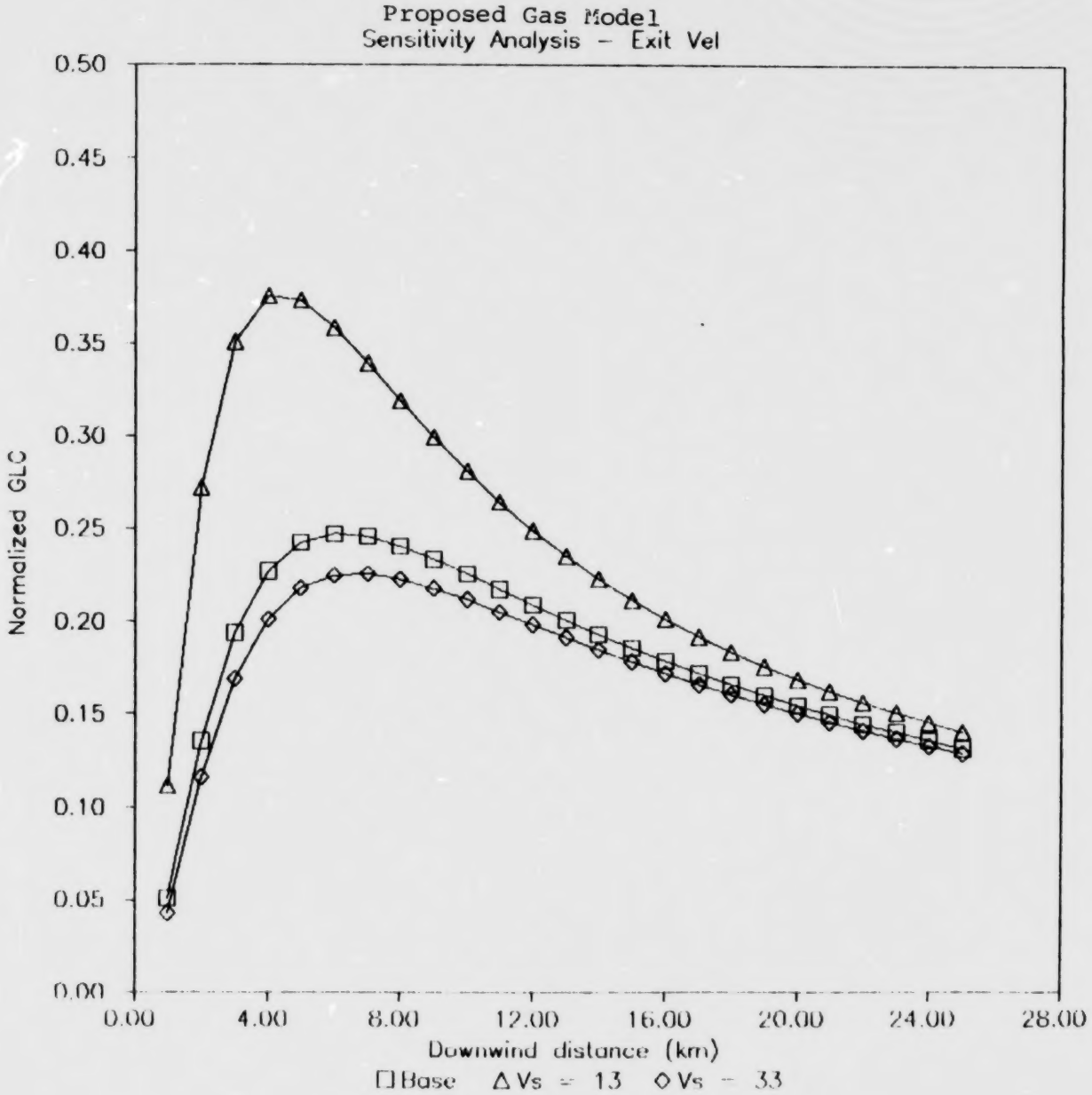
Ts - Stack exit temp (%C), Vs - Stack exit velocity (m/s)

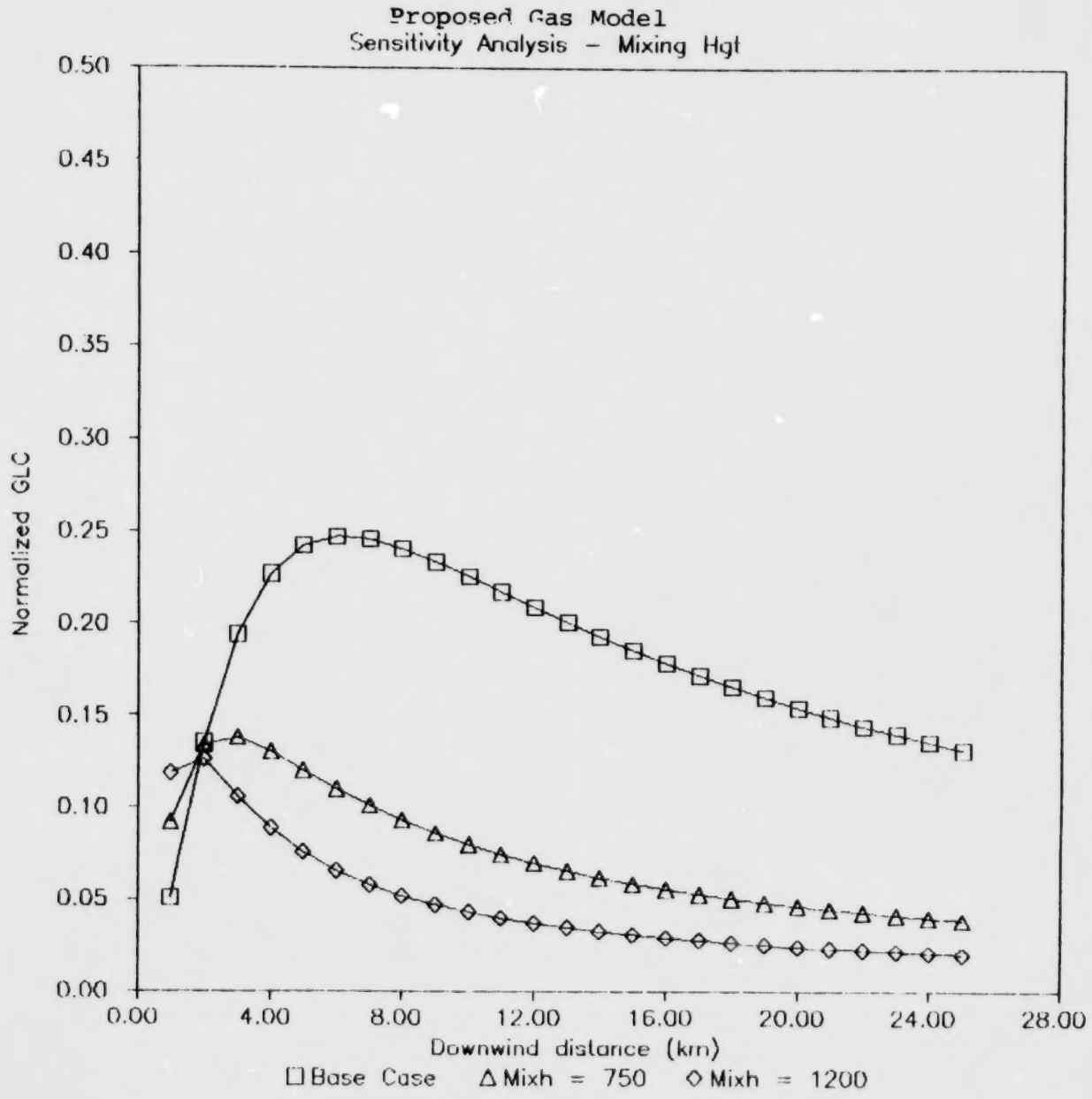
Proposed Gas Model Sensitivity Analysis - u, cc

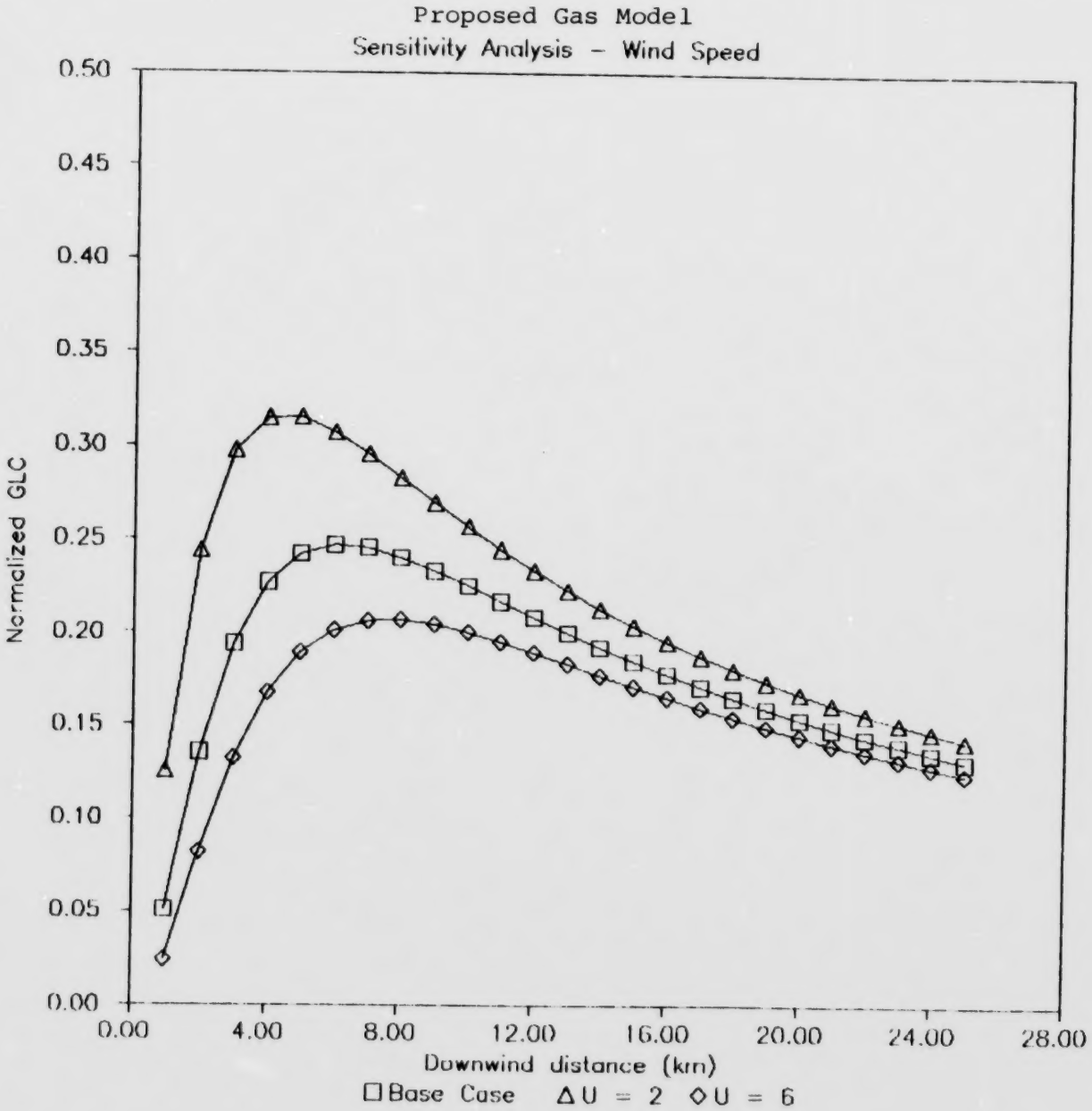


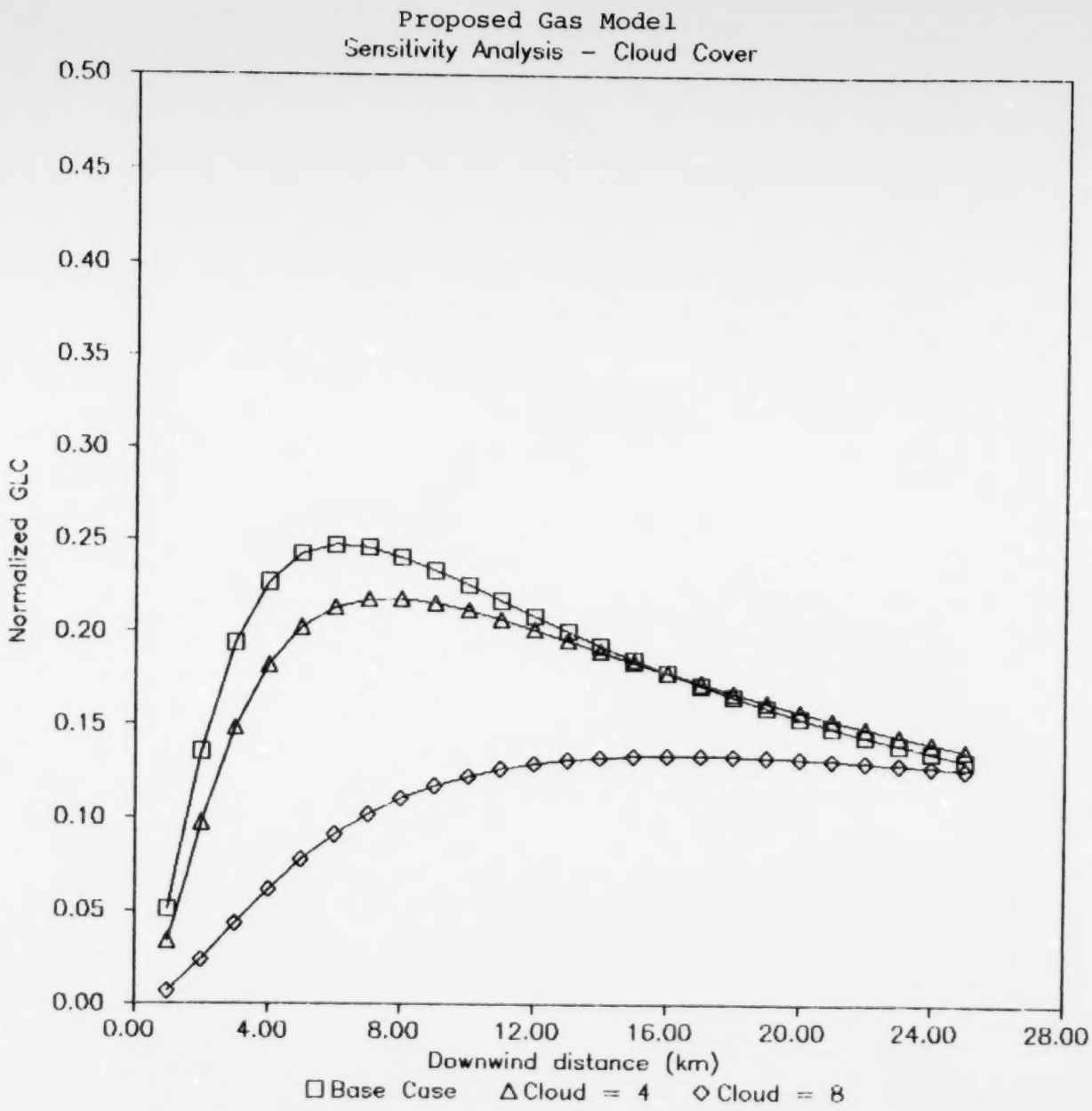
u - wind speed (m/s), cc - cloud cover (oktas)

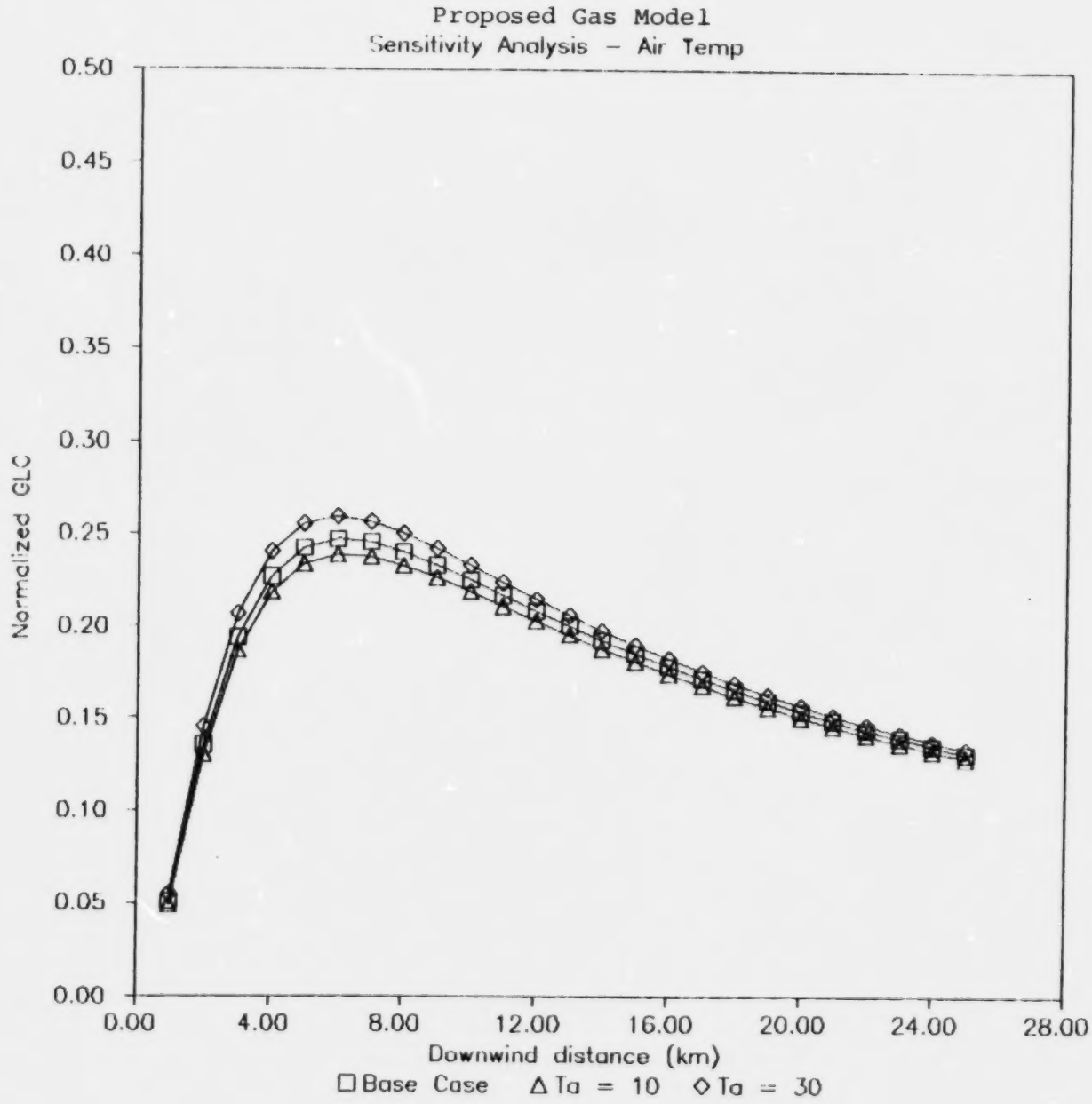

Proposed Gas Model
Sensitivity Analysis - Stack Temp
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
□ Base
△ Ts = 50
◇ Ts = 110
× Ts = 150

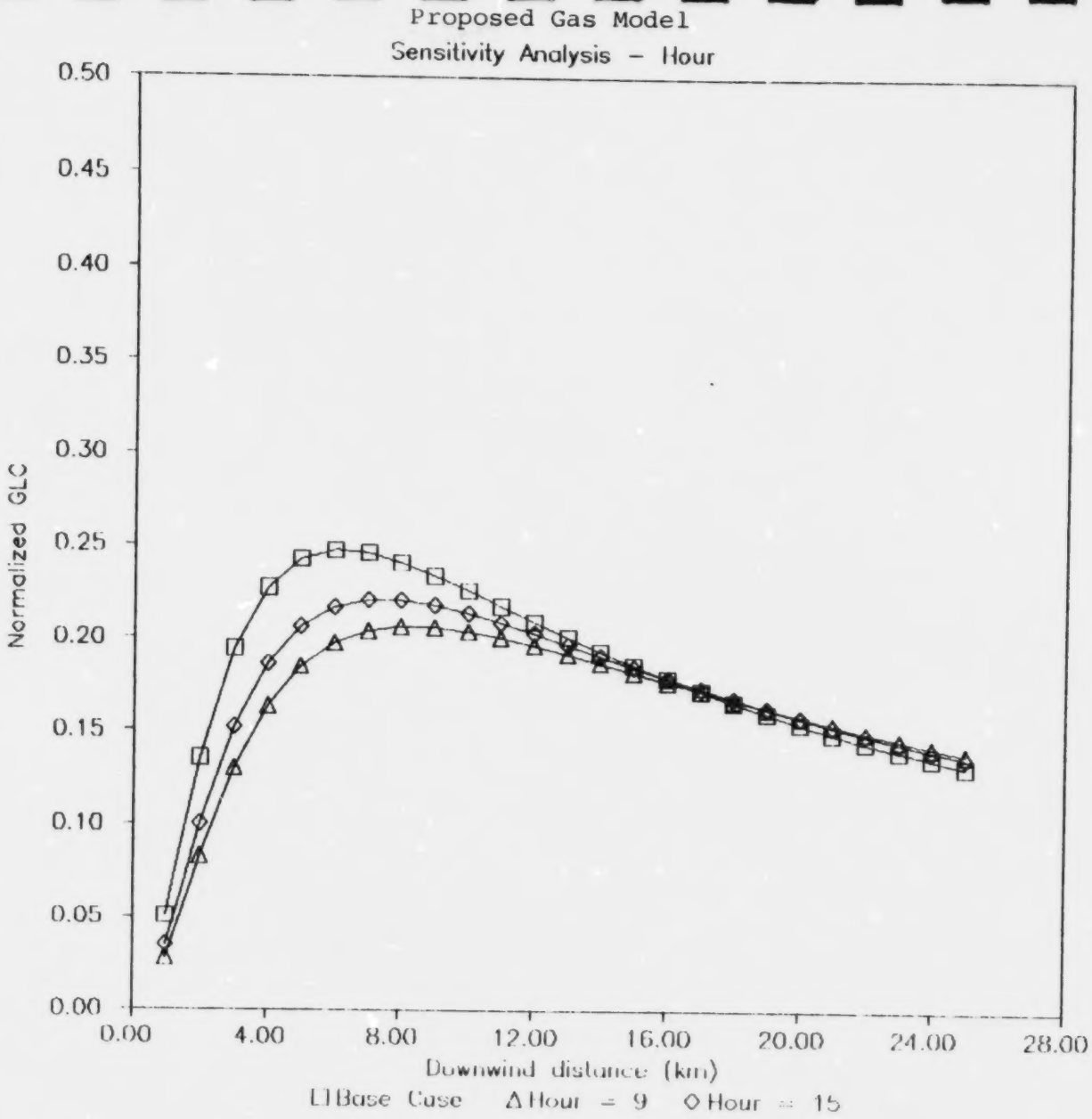

Proposed Gas Model
Sensitivity Analysis - Exit Vel
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
□ Base △ Vs = 13 ◇ Vs = 33


Proposed Gas Model
Sensitivity Analysis - Mixing Hgt
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
Base Case
Mixh = 750
Mixh = 1200


Proposed Gas Model
Sensitivity Analysis - Wind Speed
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
□ Base Case Δ U = 2 ◇ U = 6


Proposed Gas Model
Sensitivity Analysis - Cloud Cover
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
□ Base Case
△ Cloud = 4
◇ Cloud = 8


Proposed Gas Model
Sensitivity Analysis - Air Temp
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
□ Base Case
Δ Ta = 10
◇ Ta = 30


Proposed Gas Model
Sensitivity Analysis - Hour
Normalized GLC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
Downwind distance (km)
□ Base Case △ Hour = 9 ◇ Hour = 15

Proposed Lakeshore Model

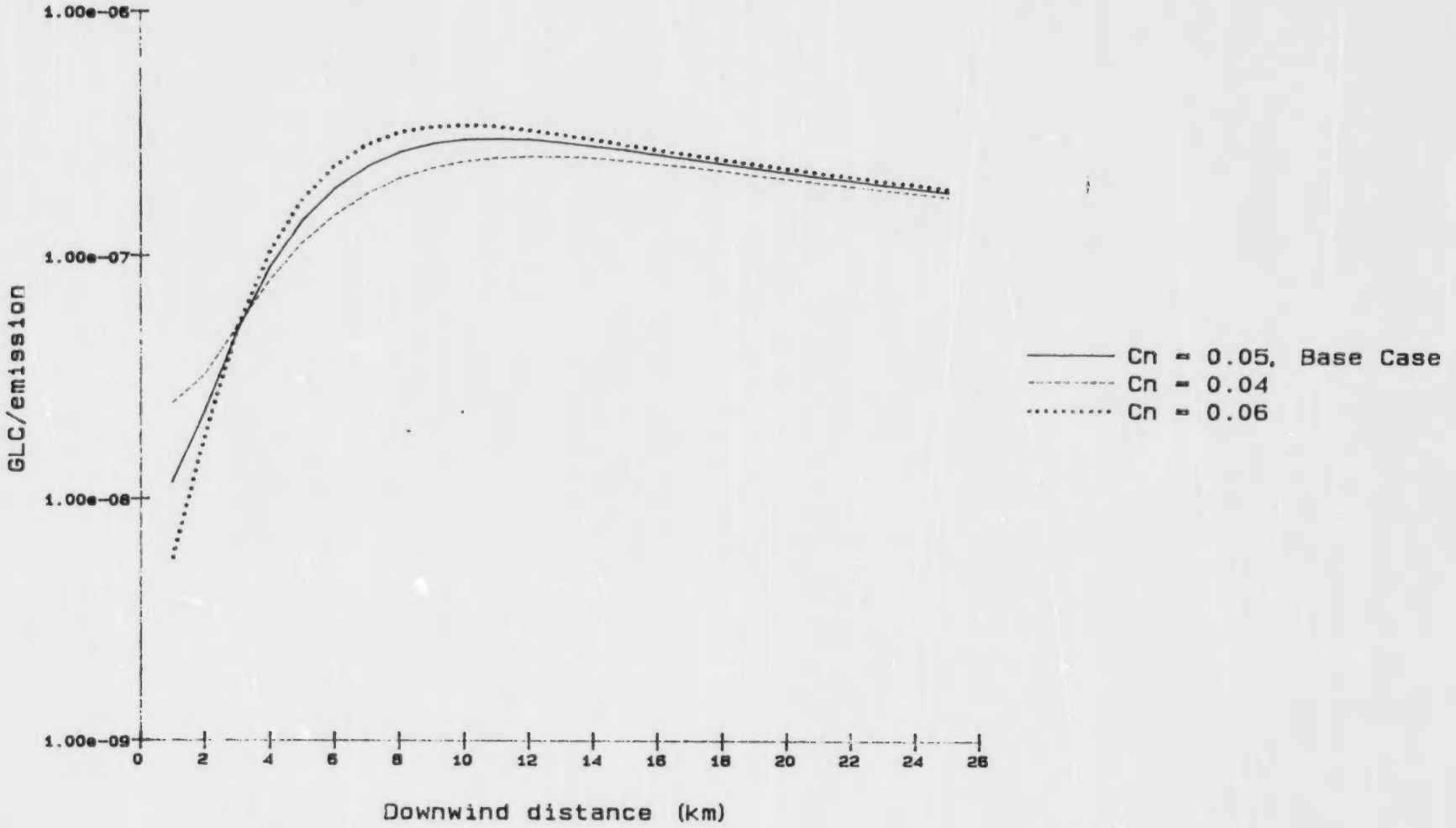
Lakeview Base Case – Sensitivity Analysis

Stack height 150.3 m
Stack diameter 5.94 m
Stack exit temperature 127° C (50° C – 150° C)
Stack exit velocity 28.4 m/s (13, 33.4)
Convective scaling velocity 1.24 m/s (.5, 2.0)
Ambient temperature 20° C (10° C, 30° C)
Wind speed 4 m/s (2 m/s, 6 m/s)
Brunt–Vaisalla frequency .05 (.04 .06)

LSENS_CN

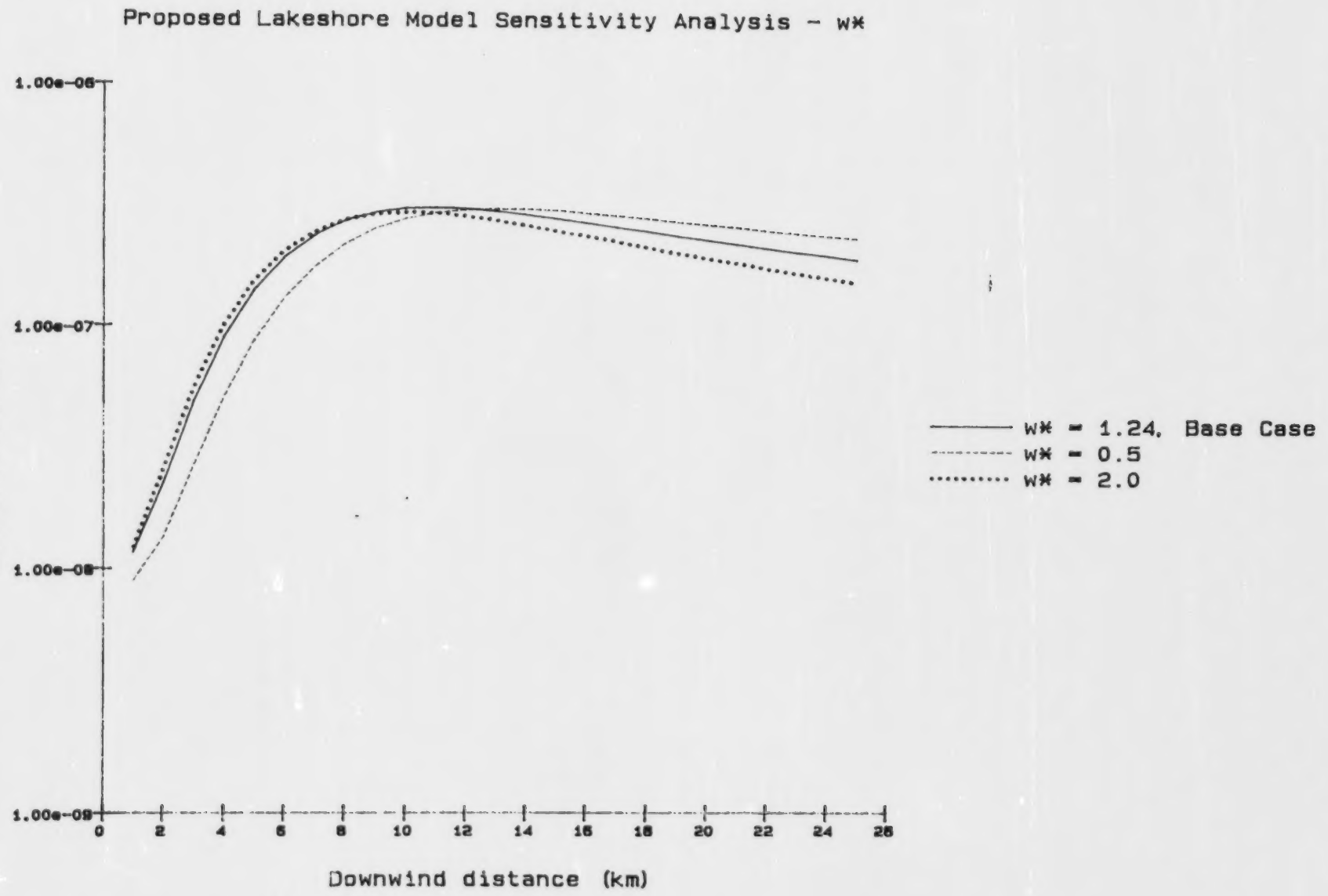
28-MAY-87 11:33 Page 1

Proposed Lakeshore Model Sensitivity Analysis - Cn

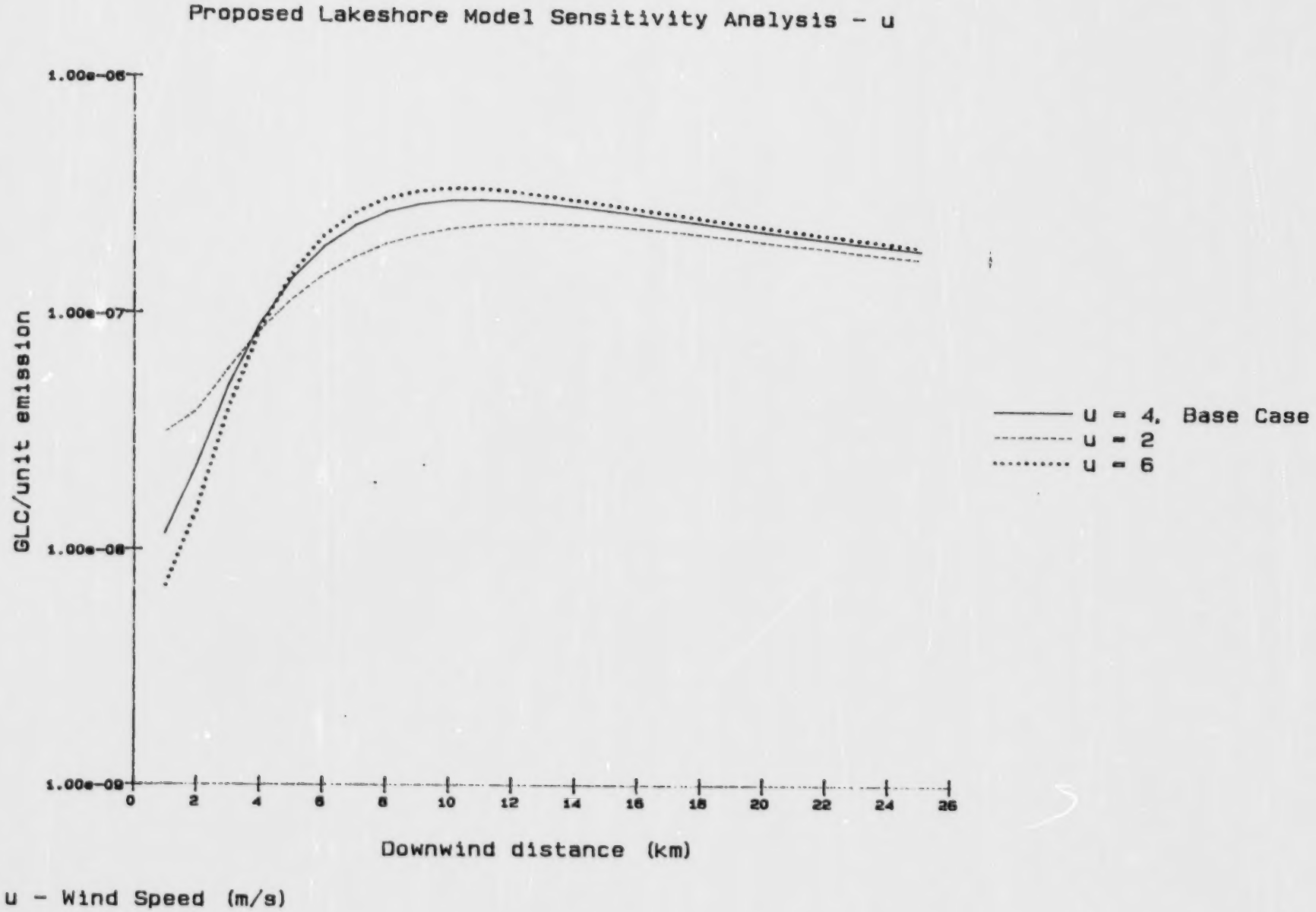


Cn - Brunt Vaisalla Frequency

87-240

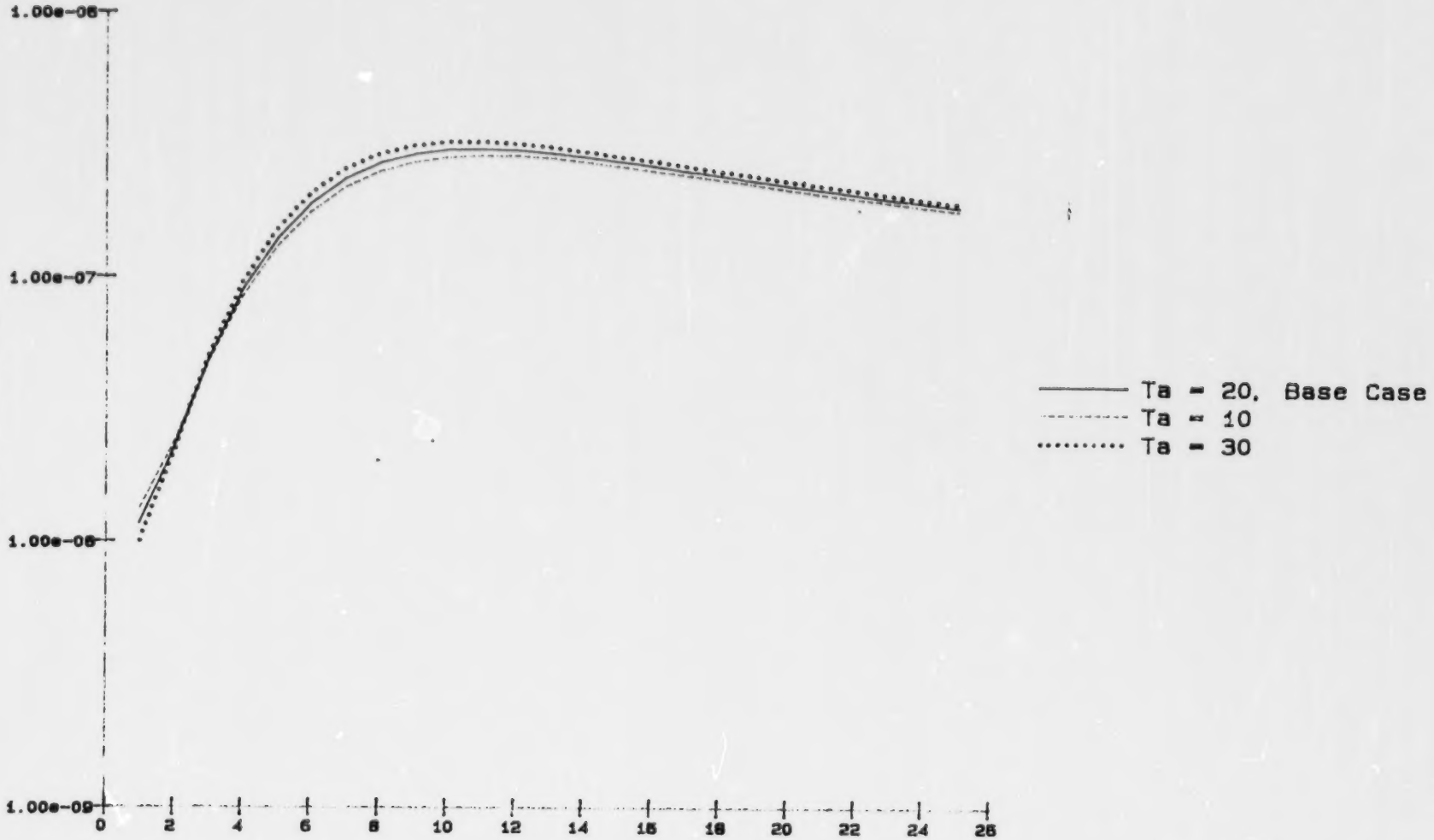


w* - Convective Scaling Velocity (m/s)



u - Wind Speed (m/s)

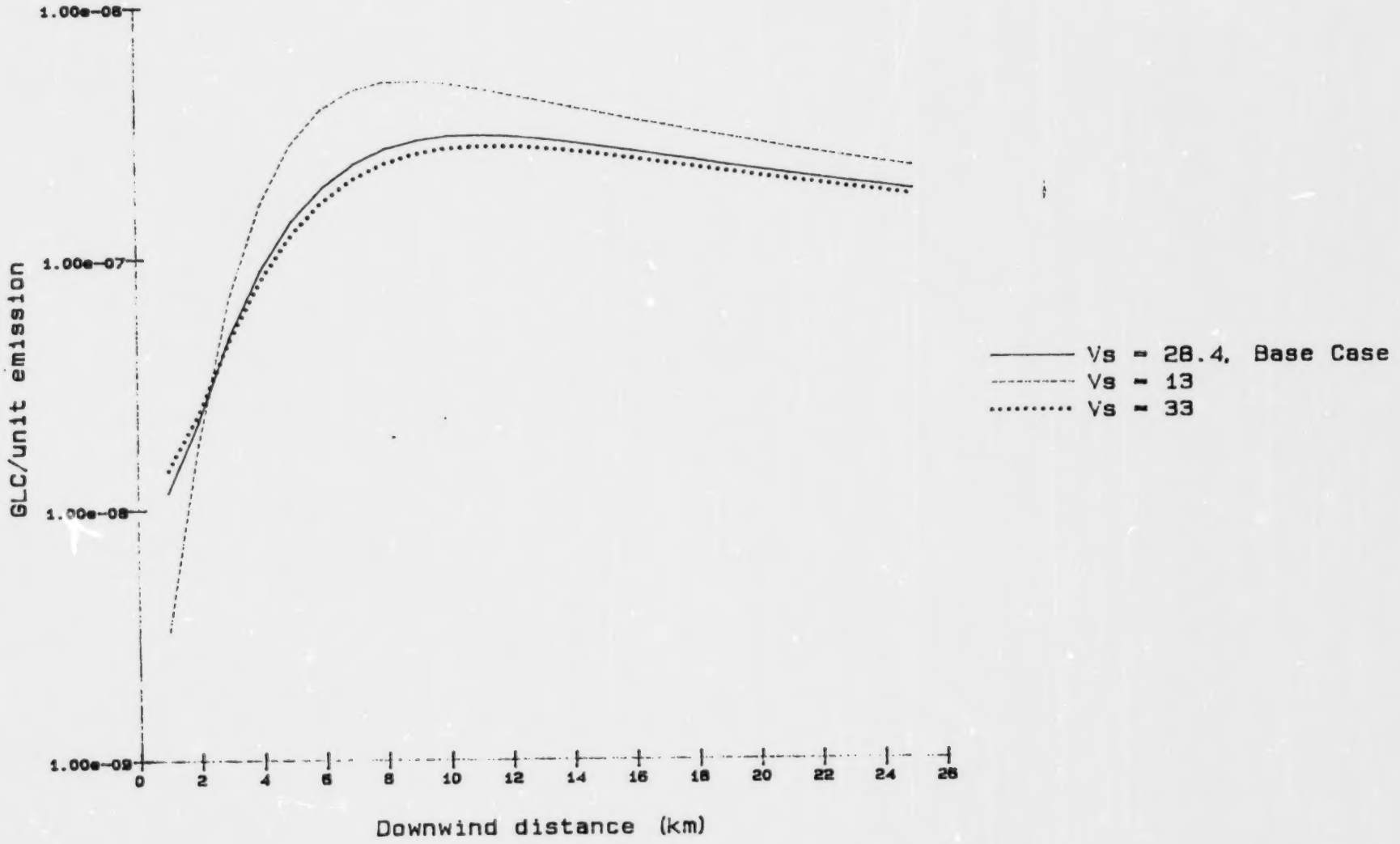
Proposed Lakeshore Model Sensitivity Analysis -- Ta



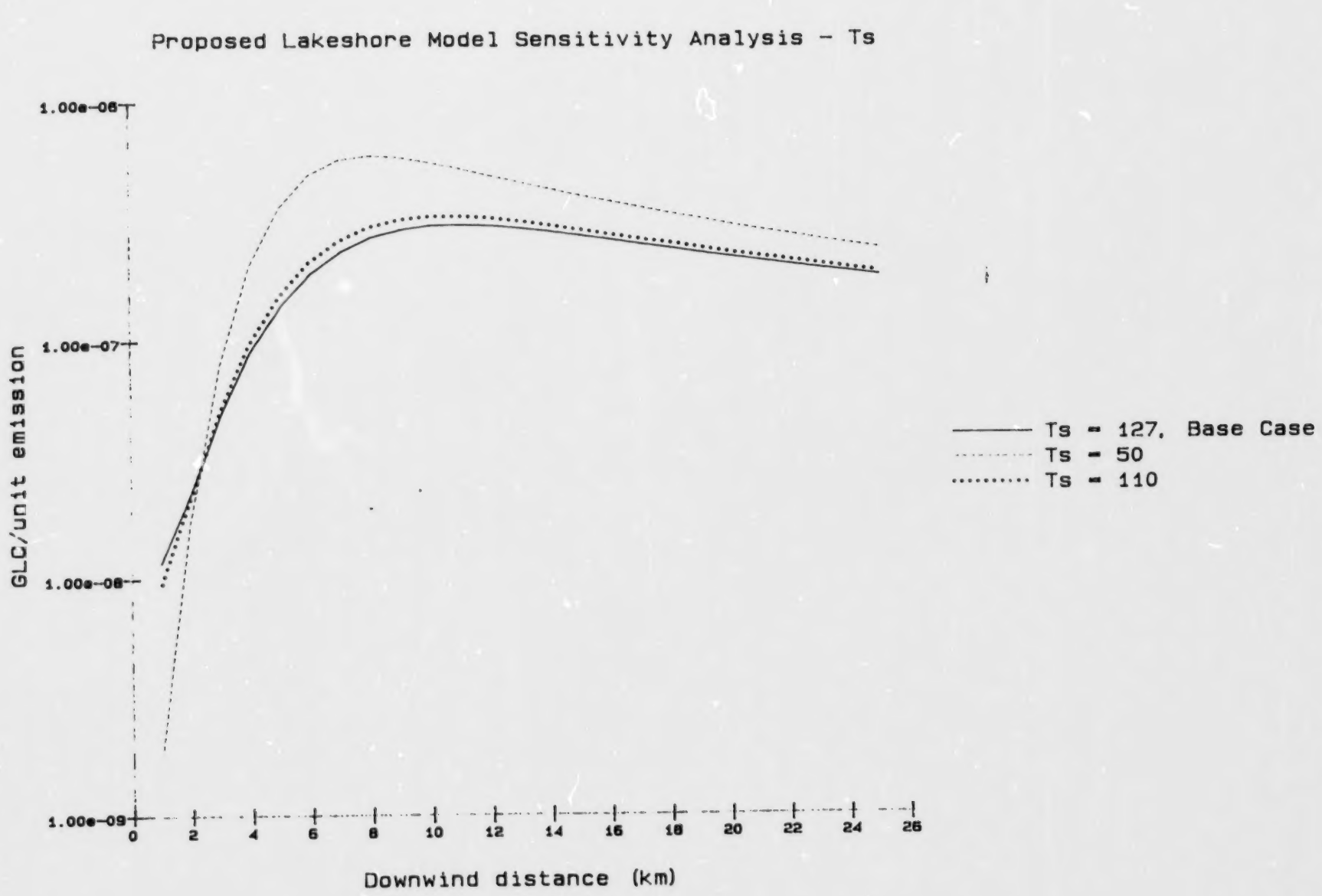
87-240

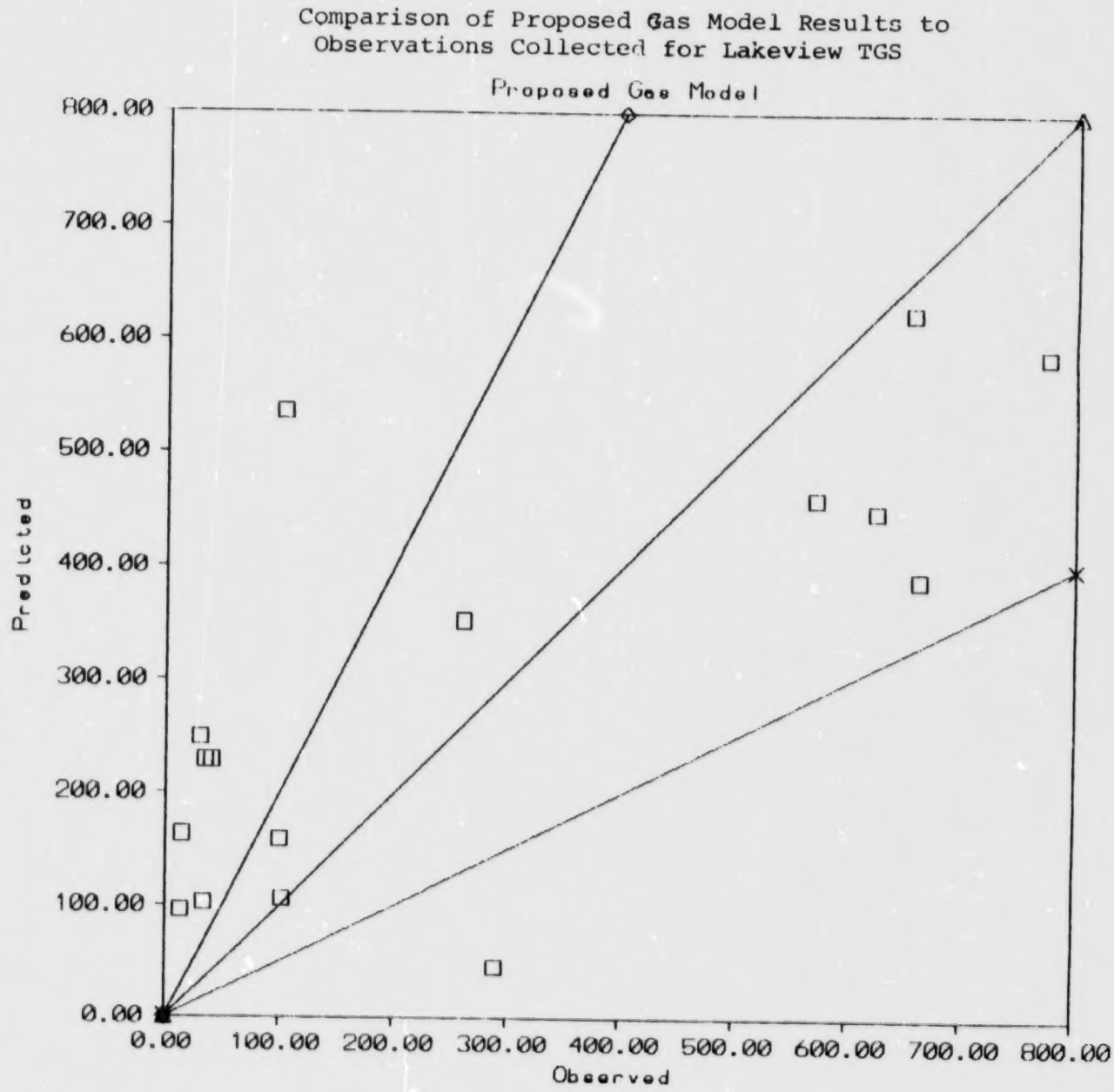
Ta - Ambient Temperature (%C)

Proposed Lakeshore Model Sensitivity Analysis - Vs



Vs - Stack Exit Velocity (m/s)


Proposed Lakeshore Model Sensitivity Analysis - Ts
1.00e-06
1.00e-07
1.00e-08
1.00e-09
GLC/unit emission
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Downwind distance (km)
Ts = 127, Base Case
Ts = 50
Ts = 110
Ts - Stack Exit Temperature (%C)


Comparison of Proposed Gas Model Results to
Observations Collected for Lakeview TGS
Proposed Gas Model
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Predicted
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
Observed

APPENDIX B

MEP AND CONCORD SCIENTIFIC PRESENTATIONS AT THE JOINT PCAO/APCA ANNUAL CONFERENCE APRIL 5-7, 1987

INSIGHTS INTO THE PROPOSED REGULATION 308 MODELS: TESTING AND APPLICATION EXPERIENCE

E. Alp, Concord Scientific Corporation

Abstract of the paper presented at the

Spring 1987 PCAO/APCA Joint Annual Conference

Toronto
April 1987

INSIGHTS INTO THE PROPOSED REGULATION 308 MODELS: TESTING AND APPLICATION EXPERIENCE

E. Alp, Concord Scientific Corporation

Spring 1987 PCAO/APCA Joint Annual Conference, Toronto

1. Introduction

The proposed Regulation 308 models (OME, 1986) constitute a giant step in incorporating the scientific advances of the last 20 years into the regulatory framework. Due to the size of this step, it is essential that these models be examined in detail before they can be used by the air pollution control community with any confidence. From a consultant's point of view, whose main line of work is advising industrial clients regarding the air pollution-related impacts of their Ontario facilities, it is therefore imperative that each and every model within the proposed regulations be dissected equation by equation so that the interactions between various prescribed algorithms and their implications in terms of their representation of the physics of the atmosphere are thoroughly understood for proper interpretation of the results. To this end, Concord has decided to build its own computer modelling system based on the theoretical descriptions provided by the Ontario Ministry of the Environment. The modelling system consists of three modules: the meteorological preprocessor, which accesses the hourly digital archives of the Atmospheric Environment Service and produces the hourly meteorological input required for the dispersion module, the statistical processor, which analyses the meteorological input for joint occurrences of important parameters as required, and the dispersion module, which estimates the ground level concentrations using the prescribed dispersion models. The dispersion module is capable of producing concentration fields on an hourly basis for the total length of the period of analysed meteorological data (usually 5 years), or on an as selected basis, based on

the results from the statistical processor. The statistical processor is also capable of analyzing the output of the dispersion module for extreme concentrations and frequency distributions.

The objective of this paper is to discuss some of the weaknesses identified during the use of the modelling system and possible improvements. Some statistics on the results from the meteorological preprocessor and comparisons of the proposed dispersion coefficients with more customary formulations are also presented.

2. Estimation of inversion height for the unstable boundary layer

Estimation of the convective boundary layer height z_i accurately from readily available measurements for any given nour is difficult at best since it has a strong time dependence, much more than most of the other parameters of interest. The recommended method in the proposed regulation models to estimate z_i is based on the nearest rawinsonde temperature versus height profiles. These profiles are available twice a day from upper air stations, of which there is only 1 in Ontario. Other parameters of interest are estimated based on hourly measurements at the nearest surface station of which there are 17 in Ontario. The question of representativeness is therefore compounded for z_i since on the average our site of interest is much further away from an upper air station than a surface station. Moreover, there is the additional inconvenience of having to merge meteorological archives from two meteorological stations. For these reasons, a simple method which requires only the hourly measurements from surface stations is proposed here for use with the regulation models. This method may result in a sacrifice in accuracy to a certain extent, but it is felt that it will be sufficient for regulatory purposes. The method is based on a simple heat balance between the heat flux from the ground since the time of sunrise on any given day and the sensible heat that goes into the air mass within the convective boundary layer.

3. The low-wind stable boundary layer

The correlations used in the regulatory models for estimating the two most important parameters of the stable boundary layer are

$$u_* = Ku_{ref}/[\ln(z_{ref}/z_0) + 4.7\ (r_{ref}/L)]$$

and

$$L = 1100\ u_*^2\ .$$

These equations are solved simultaneously for u_* and L. However, for $u_{ref} < u'_{ref} = (2/K)[\ln(z_{ref}/z_0)(4.7\ z_{ref}/1100)]^{1/2}$, there is no real solution of these equations. In the regulatory models u'_{ref} (which equals ~ 2.5 m/s for a 10 m reference height and z_0 = 10 cm (high grass)) is then used as a low-wind cut-off value in all the remaining calculations wherever a windspeed is required. This cut-off is rather high, and when the formulation for concentration estimates is considered (concentration proportional to $1/u_{ref}$), this might lead to underpredictions of ground-level concentrations. It is thus suggested that, first of all, the definition of $L = - u_*^3 T_a \rho_a C_{pa}/(gKH_0)$ be used instead of the simple correlation given above, resulting in a less restrictive u_{ref} cut-off, and secondly, but perhaps more importantly, that the u_{ref} cut-off be used only in the estimation of the above parameters, and the actual u_{ref} used in the final concentration estimates.

Low-wind stable situations are very difficult to model mainly due to lack of good quality data. Therefore, it is likely that we will see further changes in the formulation of these models, especially to take into account of meandering and the significant vertical inhomogeneities in the turbulence structure resulting in asymmetric dispersion of plumes about their centreline.

4. Use of plume-height windspeed in plume rise estimates

The proposed models assume a uniform windspeed profile in the vertical. This may lead to overestimates of plume rise leading to underestimates of ground-level concentrations. It is therefore suggested that a simple windspeed profiling method be used for estimating windspeeds at the plume height and these plume-height windspeeds be used in estimating the plume height (clearly this would lead to some inconvenience due to the required iterations). It is also suggested that the plume height windspeed be as well utilized in the final estimation of concentration instead of the reference windspeed to avoid unnecessary conservatism in ground-level concentrations.

5. Comparison of dispersion coefficients

Figures 1-13 show some comparisons of the lateral dispersion coefficients of the proposed regulatory models and those given by commonly used power law approximations to Turner's (1970) curves (σ_y, in m, x in km).

$$\text{Neutral (D class):} \quad y = 68\ (x)^{0.88},$$
$$\text{Stable (F class):} \quad y = 34\ (x)^{0.88}.$$

Figure 1 is for a neutral atmosphere with relatively high winds. The proposed models lead to somewhat lower dispersion coefficients. This implies that, for an elevated plume, the ground level concentrations may be lower nearer to the stack but higher away from the stack, when compared to standard methods.

Figures 2 and 3 are for a stable atmosphere, but for relatively high and low wind speed situations, respectively. These figures also reflect the importance of the height dependence of the dispersion coefficients in the proposed regulatory models, where turbulence is assumed to decay to zero as the plume height approaches the height of the stable boundary layer ($z_p/h \to 1$). For a low level plume (Figure

2), the lateral dispersion coefficients are much larger for the proposed models, but at a higher level (Figure 3) they are very similar to the commonly used values. At yet higher levels nearer to the boundary layer height, the trend will be reversed.

6. Conclusions

The proposed Regulation 308 models represent significant improvements over the existing and more commonly used formulations in the sense that they reflect the physics of the atmosphere much more rigorously. Further minor improvements would result in increased convenience in usage as well as in better representation of the underlying physics.

7. References

OME (1986) "Air Quality Models Suitable for Regulatory Applications." Ontario Ministry of the Environment, June Revision.

Turner, D.B. (1970) Workbook of Atmospheric Dispersion Estimates, U.S.EPA.

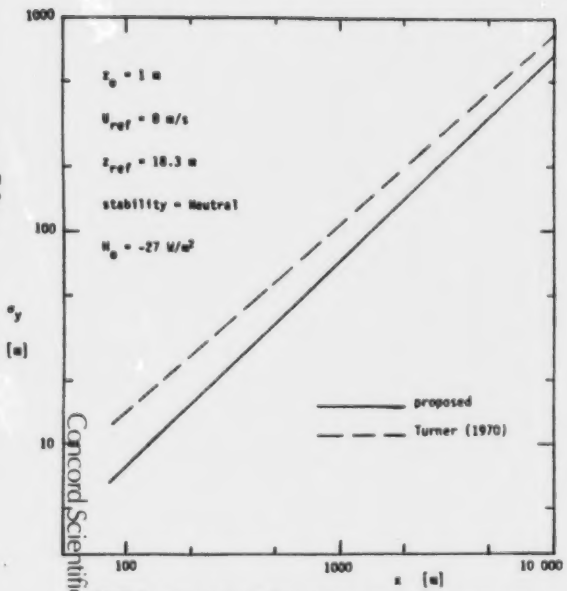


FIGURE 1. Comparison of dispersion coefficients for a neutral atmosphere.

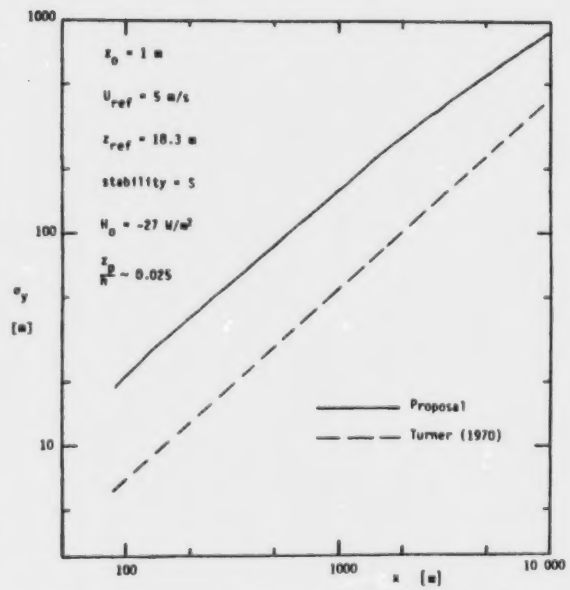


FIGURE 2. Comparison of dispersion coefficients for a high-wind stable atmosphere.

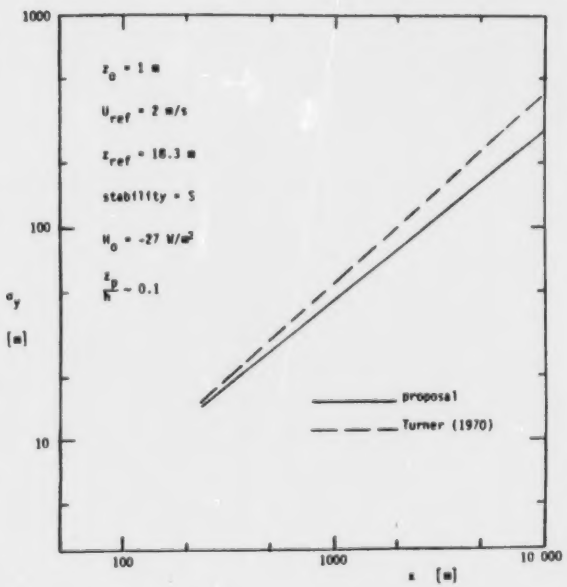


FIGURE 3. Comparison of dispersion coefficients for a low-wind stable atmosphere.

Concord Scientific Corporation

INSIGHTS INTO THE PROPOSED

REGULATION 308 MODELS:

TESTING AND APPLICATION EXPERIENCE

E. ALP

CONCORD SCIENTIFIC CORPORATION

APRIL, 1987

- THE PROPOSED MODELS REPRESENT A SIGNIFICANT DEPARTURE FROM WHAT HAS BEEN USED IN THE REGULATORY FRAMEWORK IN THE PAST 20 YEARS

- THE PROPOSED MODELS INCORPORATE THE SCIENTIFIC ADVANCES OF RECENT YEARS

- NEED TO EXAMINE IN DETAIL THE THEORY BEHIND THESE MODELS BEFORE APPLYING THEM IN A REGULATORY FRAMEWORK

- CONCORD HAS DEVELOPED A MODELLING SYSTEM ON A MICROCOMPUTER STARTING WITH THE BASIC MODEL EQUATIONS

- THIS ENABLED US TO EXAMINE THE BEHAVIOUR OF EACH AND EVERY MODULE IN AS MUCH DETAIL AS NEEDED

THE MODELLING SYSTEM CONSISTS OF FOUR BASIC MODULES:

1. METEOROLOGICAL PREPROCESSOR

2. STATISTICAL PREPROCESSOR

3. DISPERSION MODULE

4. STATISTICAL POSTPROCESSOR

1. METEOROLOGICAL PREPROCESSOR

- ACCESSES HOURLY (AND DAILY) DIGITAL ARCHIVES OF THE AES

- PRODUCES HOURLY METEOROLOGICAL INPUT REQUIRED FOR THE DISPERSION MODULE

2. STATISTICAL PREPROCESSOR

- ANALYSES THE HOURLY METEOROLOGICAL INPUT FOR JOINT OCCURRENCES OF IMPORTANT PARAMETERS AS REQUIRED.

3. DISPERSION MODULE

- PRODUCE CONCENTRATION FIELDS ON AN HOURLY BASIS FOR THE PERIOD OF ANALYSED METEOROLOGICAL DATA (~ 5 YEARS)

- PRODUCES CONCENTRATION FIELDS FOR SELECTED COMBINATIONS OF THE METEOROLOGICAL INPUT PARAMETERS (SELECTED BASED ON STATISTICAL ANALYSIS)

- OUTPUT IS IN THE FORM OF MAXIMUM HOURLY CONCENTRATIONS OF FOR SELECTED DISTANCES UNDER THE PLUME CENTRELINE

4. STATISTICAL POSTPROCESSOR

- PRODUCES FREQUENCY DISTRIBUTION OF CONCENTRATION FIELDS (USUALLY FOR HOURLY MAXIMUM CONCENTRATIONS, BUT CAN BE DONE FOR SELECTED LOCATIONS)

THE ADVANTAGE OF PRODUCING HOURLY DATA IS TO AVOID UNREALISTIC COMBINATIONS OF METEOROLOGICAL INPUT PARAMETERS WHICH MIGHT LEAD TO UNREALISTIC CONCENTRATION ESTIMATES.

SUGGESTED IMPROVEMENTS TO THE PROPOSED MODELS

- ESTIMATION OF INVERSION HEIGHT FOR THE UNSTABLE BOUNDARY LAYER
- THE LOW-WIND STABLE BOUNDARY LAYER
- USE OF PLUME-HEIGHT WINDSPEED IN PLUME RISE ESTIMATES
- CONCENTRATION FLUCTUATIONS

ESTIMATION OF INVERSION HEIGHT FOR THE UNSTABLE BOUNDARY LAYER

- PROPOSED MODELS REQUIRE RAWINSONDE TEMPERATURE PROFILES

- INCONVENIENT AND UNREPRESENTATIVE

- SUGGEST TO USE A SIMPLE BOUNDARY LAYER HEAT BALANCE MODEL FOR ESTIMATING Z_I FROM HOURLY SURFACE DATA

  PANOFSKY AND DUTTON (1984)

$$Z_I = \frac{Z}{c_p \rho \left[T(T) - T(T_0) \right]} \int_{T_0}^{T} H_0 \, DT$$

  T_0 = TIME OF MINIMUM TEMPERATURE

- SUFFICIENT FOR REGULATORY PURPOSES.

THE LOW-WIND STABLE BOUNDARY LAYER

- THE CORRELATION SET USED FOR U* AND L DOES NOT HAVE A SOLUTION FOR LOW WINDS.

- IN THE PROPOSED REGULATION 308 MODELS, THE MINIMUM VALUE OF WINDSPEED WHICH GIVES A SOLUTION TO THE EQUATION SET IS USED IN ESTIMATING CONCENTRATIONS.

- THIS CUT-OFF WIND SPEED IS RATHER HIGH LEADING TO <u>UNDER-PREDICTED</u> GROUND LEVEL CONCENTRATIONS

- USE OF THE DEFINITION OF L INSTEAD OF THE PROPOSED SIMPLE CORRELATION WILL EXTEND THE RANGE OF APPLICABILITY OF THE EQUATION SET, HOWEVER IT STILL LEADS TO A LOW WIND-SPEED CUT-OFF.

- IT IS SUGGESTED THAT THE ACTUAL WIND-SPEED AND NOT THIS RELATIVELY HIGH CUT-OFF SPEED BE USED IN CONCENTRATION ESTIMATION.

- THE CUT-OFF SPEED IS STILL REQUIRED IN THE ESTIMATION OF THE TURBULENT DISPERSION PARAMETERS.

- FURTHER FIELD DATA AND THEORETICAL WORK REQUIRED TO ADDRESS THE ISSUES OF MEANDERING AND VERTICAL INHOMOGENEITIES. THE PRESENTLY PROPOSED MODELS TEND TO OVERESTIMATE DUE TO OMISSION OF THESE EFFECTS.

USE OF PLUME-HEIGHT WINDSPEED IN PLUME RISE ESTIMATES

- THE PROPOSED MODELS ASSUME A UNIFORM WINDSPEED PROFILE IN THE VERTICAL, LEADING TO OVER-ESTIMATES OF PLUME RISE, WHICH IN TURN LEAD TO UNDERESTIMATES OF GROUND LEVEL CONCENTRATIONS

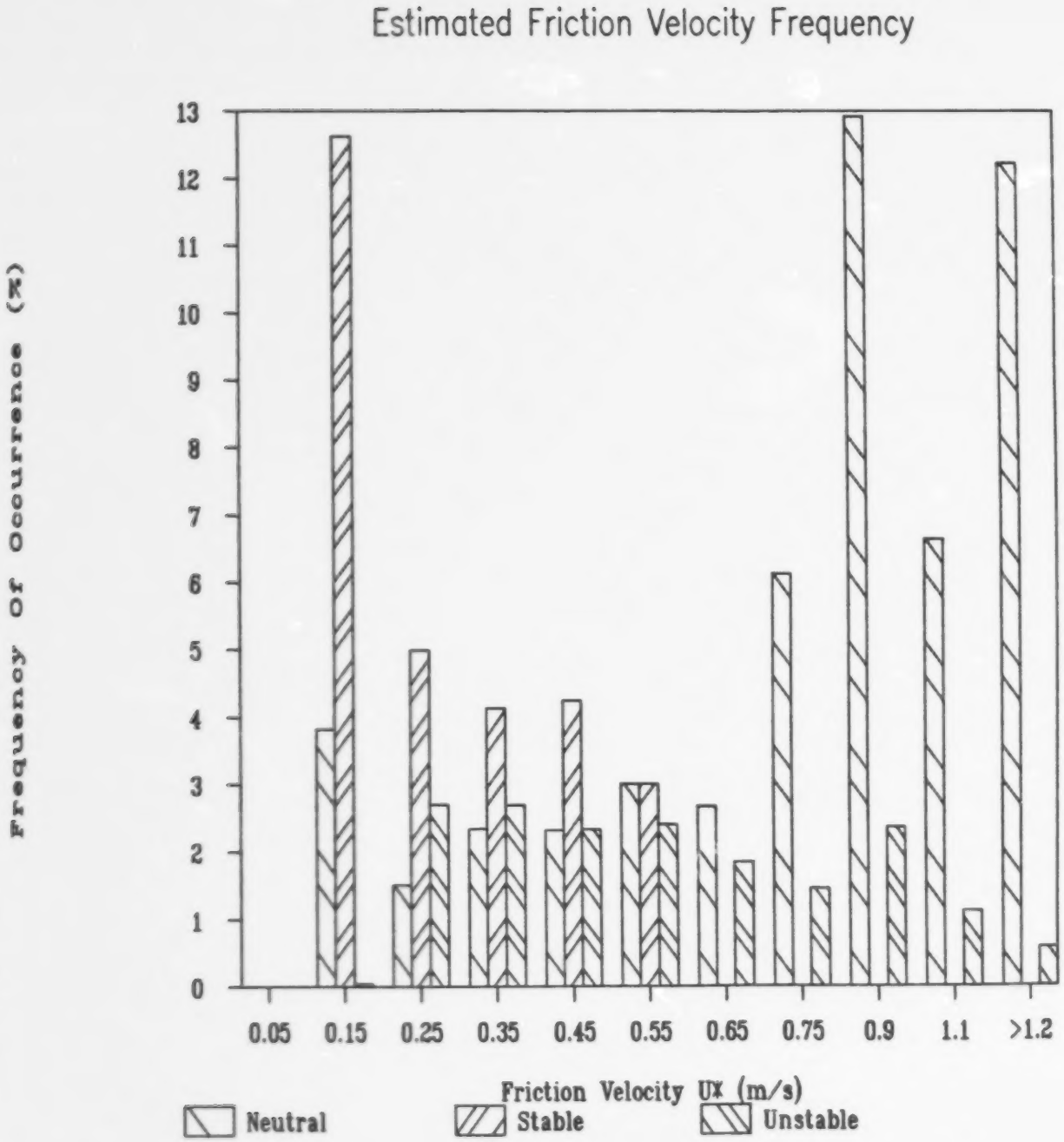
- INCLUSION OF A SIMPLE WIND PROFILE TO ESTIMATE THE PLUME-HEIGHT WINDSPEED FOR USE IN PLUME RISE CORRELATIONS WILL RESOLVE THIS PROBLEM.

CONCENTRATION FLUCTUATIONS

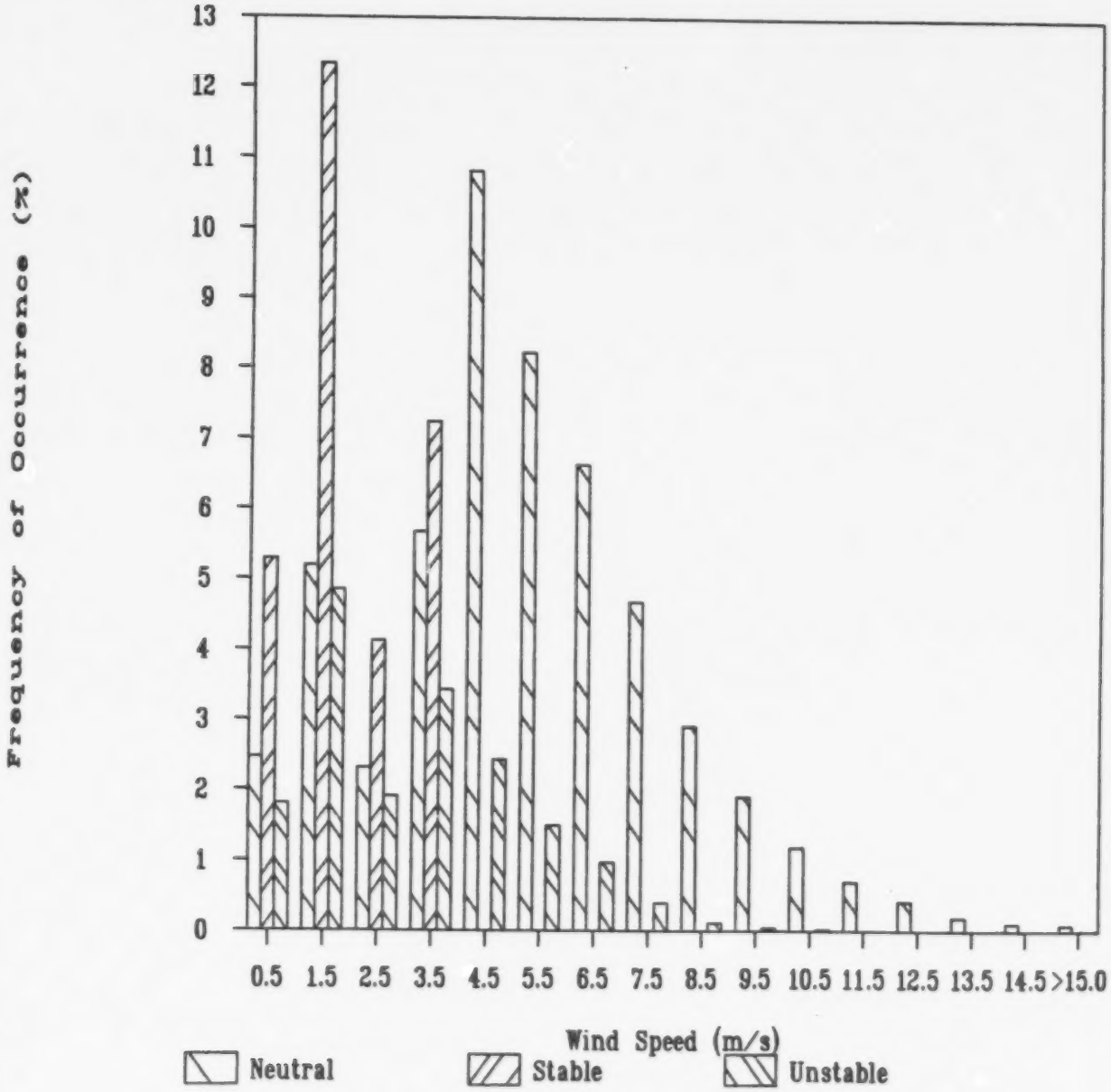
- THE PROPOSED MODELS ARE INADEQUATE FOR ESTIMATING SHORT-TERM TOXIC EFFECTS AND EFFECTS OF ODOUROUS EMISSIONS

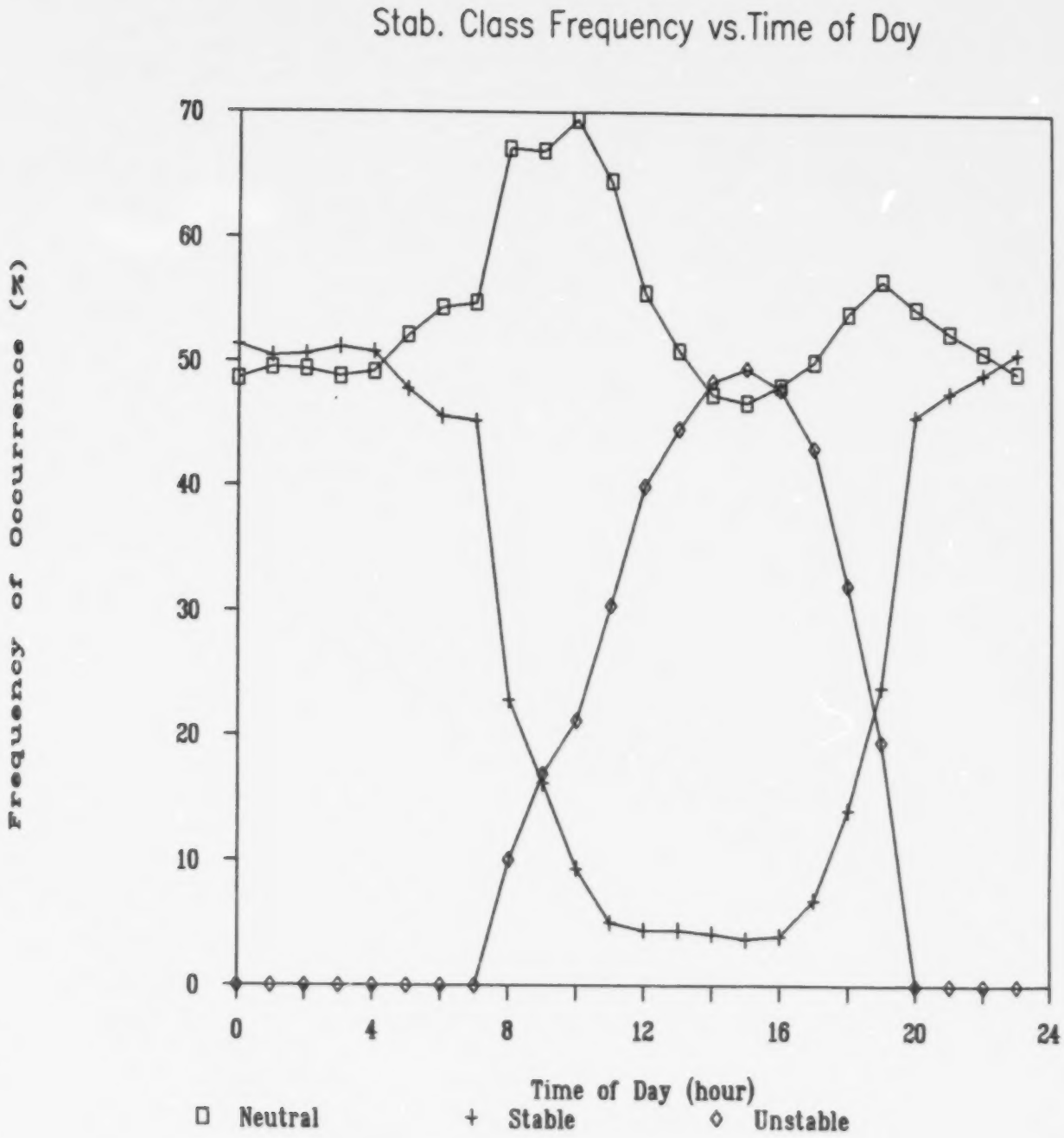
- A SIMPLE CONCENTRATION FLUCTUATION MODEL THAT WOULD ENABLE US TO ESTIMATE FREQUENCY OF OCCURRENCE OF EXCEEDING GIVEN CRITICAL CONCENTRATION LEVELS IS THUS ESSENTIAL FOR CONFIDENT ENFORCEABILITY OF THE PROPOSED MODELS.

SELECTED RESULTS FROM
THE METEOROLOGICAL PREPROCESSOR

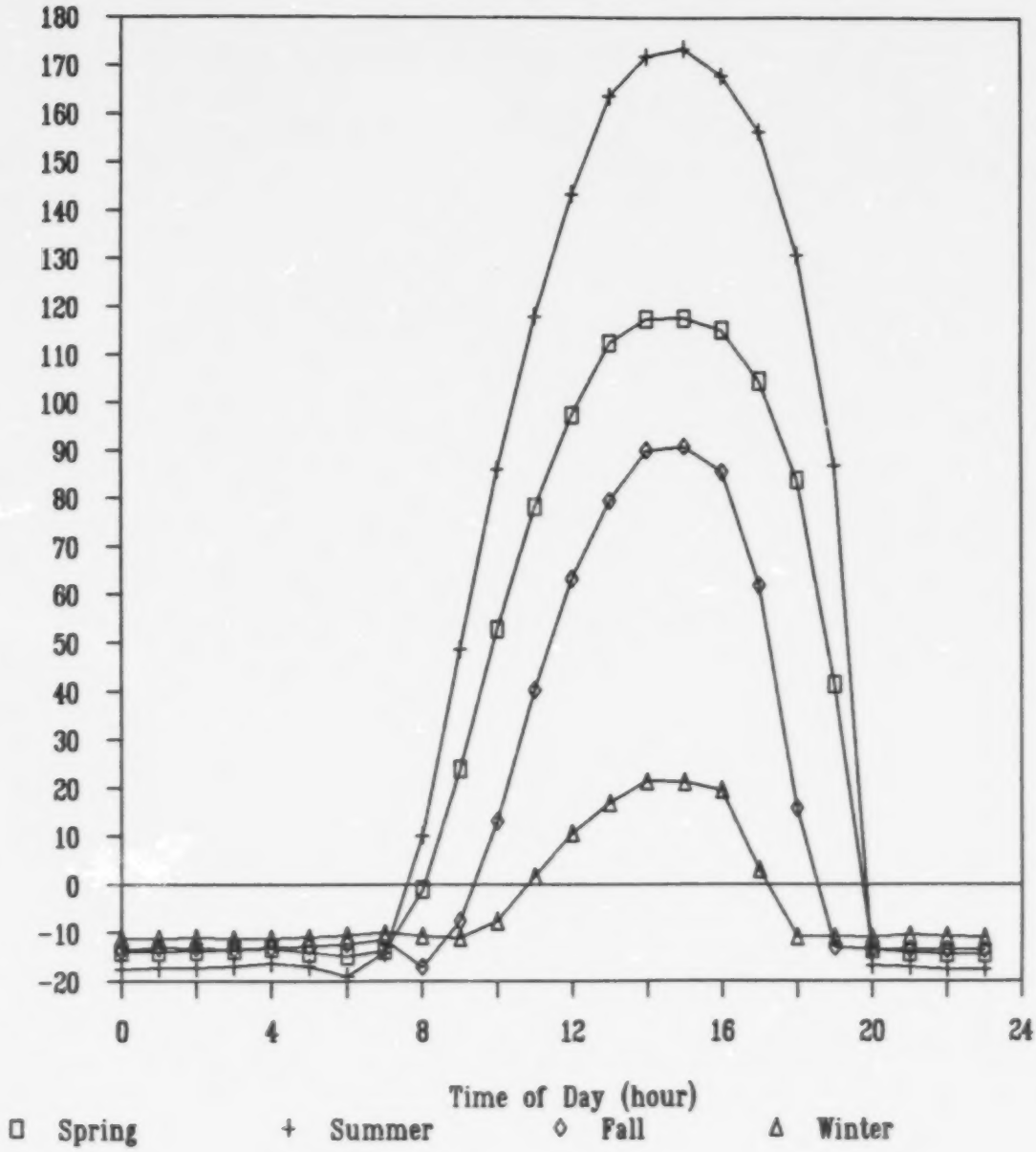

Estimated Friction Velocity Frequency
Frequency Of Occurrence (%)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0.05
0.15
0.25
0.35
0.45
0.55
0.65
0.75
0.9
1.1
>1.2
Friction Velocity U* (m/s)
Neutral
Stable
Unstable

Observed Wind Speed Frequency.

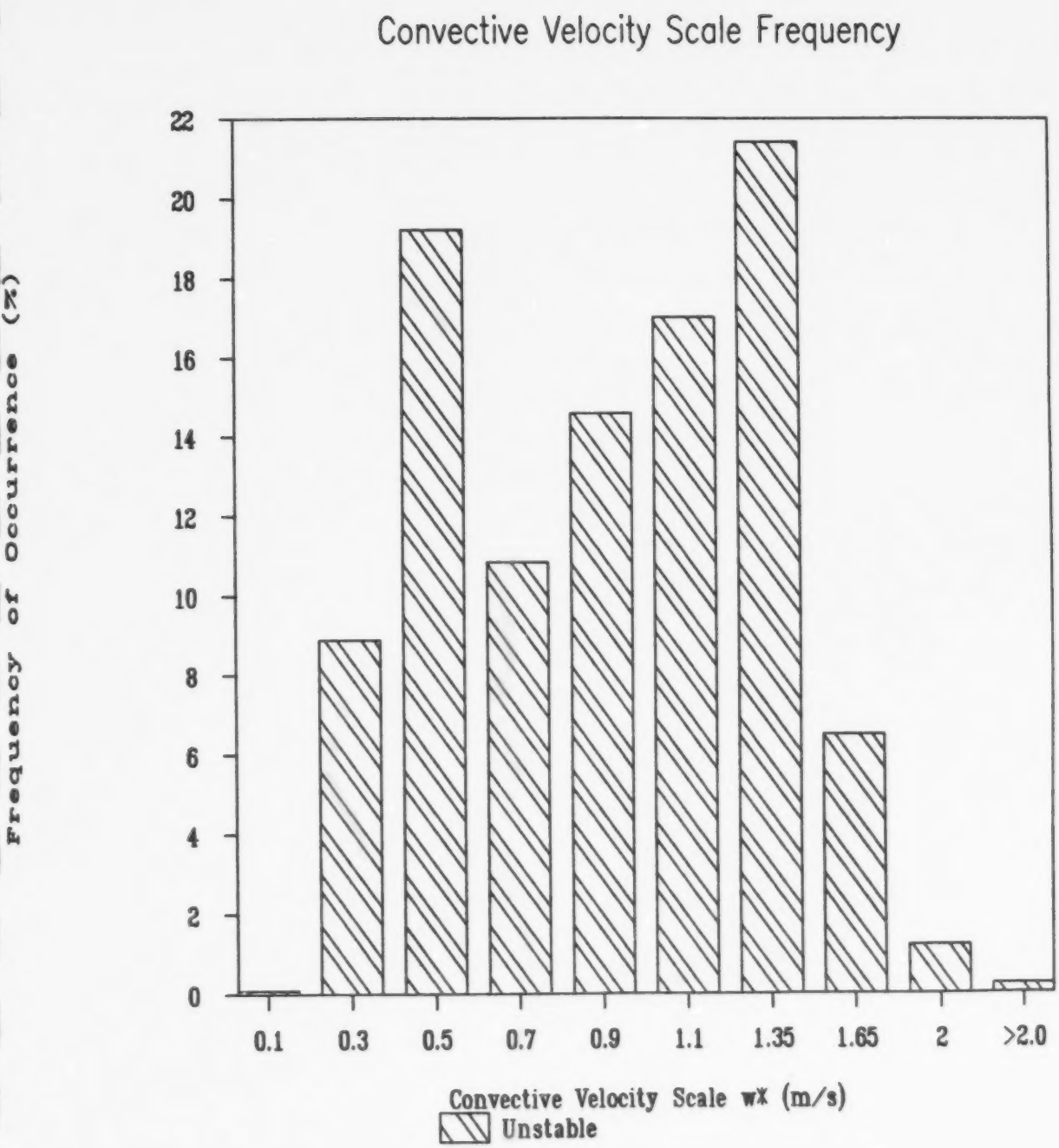



Stab. Class Frequency vs.Time of Day
Frequency of Occurrence (%)
70
60
50
40
30
20
10
0
0
4
8
12
16
20
24
Time of Day (hour)
Neutral
Stable
Unstable

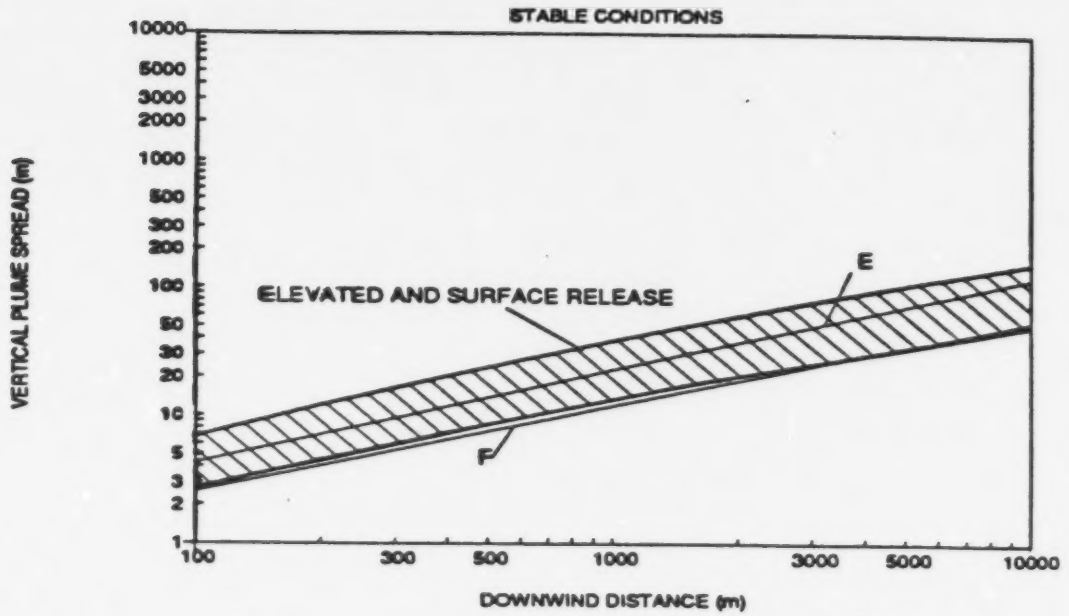
Mean Surface Heat Flux vs. Time of Day

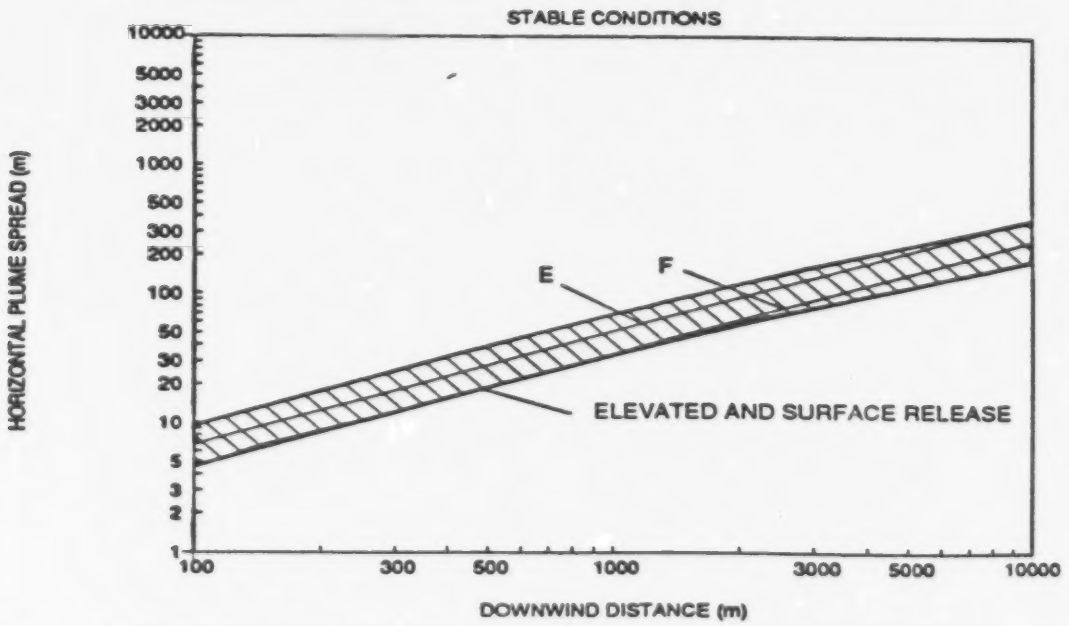


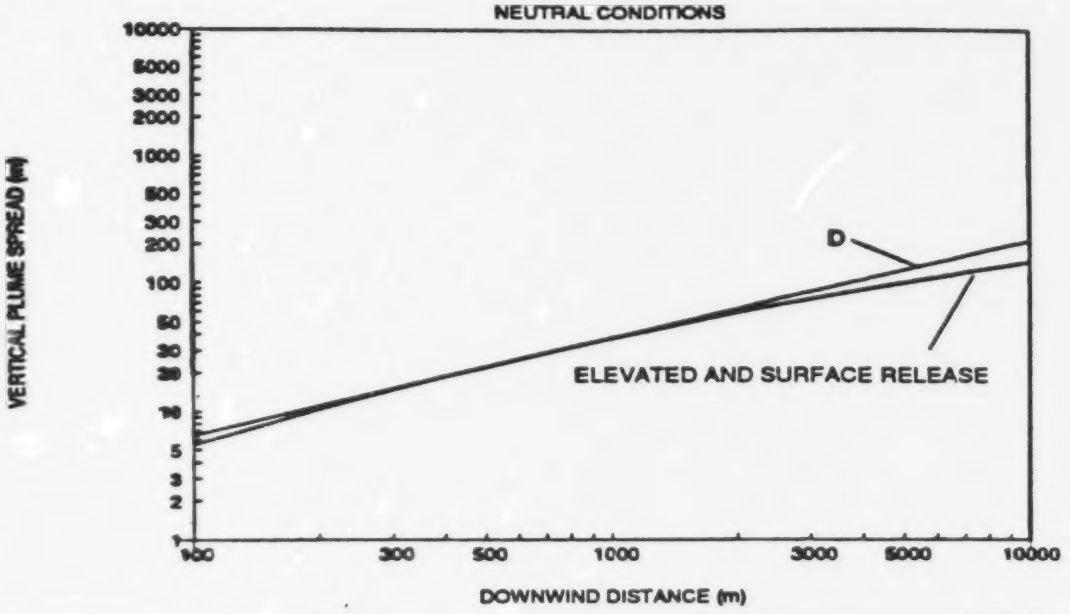
Concord Scientific Corporation

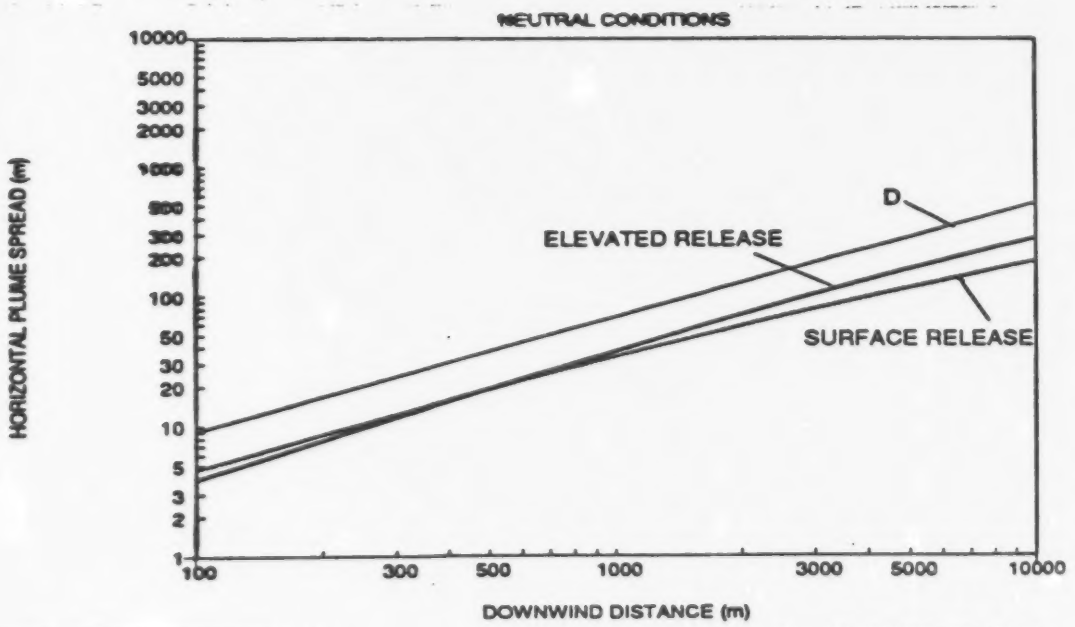

Convective Velocity Scale Frequency
Frequency of Occurrence (%)
22
20
18
16
14
12
10
8
6
4
2
0
0.1
0.3
0.5
0.7
0.9
1.1
1.35
1.65
2
>2.0
Convective Velocity Scale w* (m/s)
Unstable

COMPARISON OF DISPERSION COEFFICIENTS


STABLE CONDITIONS
VERTICAL PLUME SPREAD (m)
10000
5000
3000
2000
1000
500
300
200
100
50
30
20
10
5
3
2
1
ELEVATED AND SURFACE RELEASE
E
F
100
300
500
1000
3000
5000
10000
DOWNWIND DISTANCE (m)


STABLE CONDITIONS
HORIZONTAL PLUME SPREAD (m)
10000
5000
3000
2000
1000
500
300
200
100
50
30
20
10
5
3
2
1
E
F
ELEVATED AND SURFACE RELEASE
100
300
500
1000
3000
5000
10000
DOWNWIND DISTANCE (m)


NEUTRAL CONDITIONS
VERTICAL PLUME SPREAD (m)
10000
5000
3000
2000
1000
500
300
200
100
50
30
20
10
5
3
2
1
100
300
500
1000
3000
5000
10000
D
ELEVATED AND SURFACE RELEASE
DOWNWIND DISTANCE (m)


NEUTRAL CONDITIONS
HORIZONTAL PLUME SPREAD (m)
10000
5000
3000
2000
1000
500
300
200
100
50
30
20
10
5
3
2
1
100
300
500
1000
3000
5000
10000
D
ELEVATED RELEASE
SURFACE RELEASE
DOWNWIND DISTANCE (m)

CONCLUSIONS

- THE PROPOSED REGULATION 308 MODELS REPRESENT SIGNIFICANT IMPROVEMENTS OVER THE EXISTING AND MORE COMMONLY USED FORMULATIONS IN THE SENSE THAT THEY REFLECT THE PHYSICS OF THE ATMOSPHERE MUCH MORE RIGOROUSLY.

- FURTHER MINOR IMPROVEMENTS WOULD RESULT IN INCREASED CONVENIENCE IN USAGE, BETTER ENFORCEABILITY, AS WELL AS IN BETTER REPRESENTATION OF THE UNDERLYING PHYSICS.

PRACTICAL ASPECTS OF THE PROPOSED REGULATION 308 MODELS

KEITH C. HEIDORN

THE MEP COMPANY

1987

Location of Study Area

Source Categories for Modeling with the Proposed Regulation 308

I. Isolated Source

II. Source Located in Region Containing Many Small Sources But Isolated from Other Large Sources

III. Source Located in a Region with Several Sources (Small and Large)

A Source is "Isolated" if its "Radius of Influence" Does Not Intersect That Of Another Source.

Small Source: A Source Is Considered "Small" If Its "Worst Case " Maximum Concentration Is Less Than 30% of the Criterion for That Pollutant.

Large Source: All Sources Not Considered a Small Source.

DEFINITION:

Radius of Influence-

The Maximum Distance from A Source At Which The Concentration Falls Below 5 % Of The Air Quality Concentration For That Pollutant.

REQUIRED SOURCE PARAMETERS

1. Source Location (UTM grid coordinates)
2. Stack Height
3. Stack Radius
4. Exit Gas Temperature
5. Exit Gas Velocity
6. Emission Rate
7. Building Dimensions

WORST CASE MODEL

1. Stable:

   Loop U from Umin to Umax

   Umin = Max(1.5 m/s, Umina)

   Umina = SQRT[1.4 ln (10./Z0)]

Z0 (m)	Umina
5	1.0
1	1.8
.1	2.5
.01	3.1
.001	3.6

   Continue Loop to Umax = 15 m/s or L>500m

2. Neutral:

   Loop U from 1.5 to 15 m/s

3. Convective:

   Loop Mixed Layer Height from 50 to 3000m

   Loop Wstar from .25 to Wsar-max

   $$Wstar\text{-}max = Min[(Zl/AA)^{1/3}, 3.00)]$$

   where AA = 100 if Zl>500m

   = 100+(500-Zl)/4.5, otherwise

   Loop U from Umin to Umax

   Umin = Max(1.5m/s, 1.2Wstar)

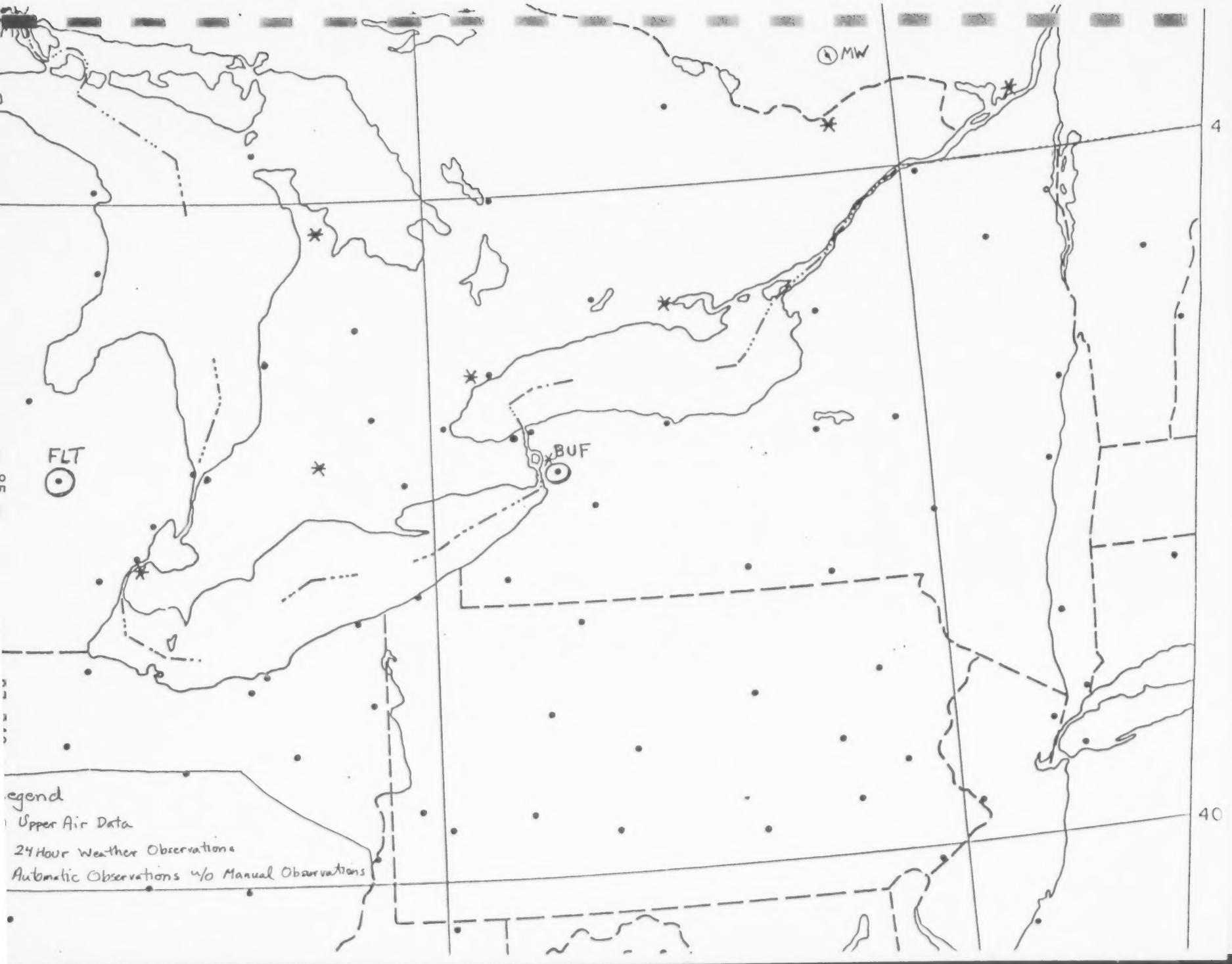
   Umax = 6 Wstar

```
CLOSEST POINT TO SOURCE =    10.00000
ROUGHNESS LENGTH (M) =  0.1500000      AIR QUALITY CRITERION (UG/M3) =
  590.0000
LARGE SOURCE CUTOFF (UG/M3) =    207.0000
RADIUS OF INFLUENCE CUTOFF (UG/M3) =    34.50000

-------------------------------------------------------------

 RESULTS FOR STABLE CASE
 RADIUS OF INFLUENCE (STABLE) =    25000.00
 MAX CONCENTRATION (UG/M3) =    552.4695
 STABLE CONDITIONS (ELEVATED)
 MAX CONCEN/Q:    11.55794    AT DISTANCE    2450.000    M
 WIND SPEED (M/S) =    3.500000    M-L LENGTH (M) =    59.40240
 USTAR (M/S) =  0.2511834    MIX. HT. (M) =    148.6462
 FM =    1.000000    DH (M) =  0.9095238

 RADIUS OF INFLUENCE (CONVECTIVE) =    25000.00
 MAXIMUM CONCENTRATION (UG/M3) =    2018.458
 CONVECTIVE CONDITIONS (ELEVATED)
 MAX CONCEN/Q:    42.22715    AT DISTANCE    305.8442    M
 WIND SPEED (M/S) =    1.500000    M-L LENGTH (M) =  -4.231411
 USTAR (M/S) =  0.1985002    WSTAR (M/S) =  0.7434817    MIX. HT. (M) =
  79.50000
 FM =    1.000000    DH (M) =    3.637230

 RADIUS OF INFLUENCE (NEUTRAL) =    14350.00
 MAXIMUM CONCENTRATION (UG/M3) =    1027.713
 NEUTRAL CONDITIONS (ELEVATED)
 MAX CONCEN/Q:    21.50026    AT DISTANCE    1030.000    M
 WIND SPEED (M/S) =    1.500090
 USTAR (M/S) =  0.1250088    MIX. HT. (M) =    375.0264
 FM =    1.000000    DH (M) =    9.157054

**************************************************
 MAXIMUM CONCENTRATION/EMISSION RATE
 MAX CONCEN/Q (CONVECTIVE) =    42.22715
 MAX CONCEN/Q (NEUTRAL)    =    21.50026
 MAX CONCEN/Q (STABLE)     =    11.55794
```

Emission Rate = 45 g s^{-1}

REQUIRED METEOROLOGICAL DATA

1. 10m Wind Speed
2. 10 m Wind Direction
3. Surface Air Temperature
4. Cloud Cover
5. Indication of Snow on the Ground
6. Vertical Temperature Profile to Calculate Convective Mixing Height
7. If Shoreline Site, TIBL Height for Onshore Flow


MW
FLT
BUF
4
40
egend
Upper Air Data
24 Hour Weather Observations
Automatic Observations w/o Manual Observations

Meteorological Processor For Proposed Reg. 308 Models

INPUT: U10, WD10, T10, Cloud Cover, Snow on the Ground, Zl, Z0, time, date, latitude, longitude

1. Calculate Clear Sky , Incoming Solar Radiation

   R = f(date, time, latitude, longitude)

2. Determine Surface Height Flux

   H0 = f(R, cloud cover, ground cover)

3. Determine Type of Stability

   If H0 > 5 w/m2,
   Convective Atmosphere
   Calculate: Ustar, Wstar, L
   If U > 6 Wstar, ==> Neutral

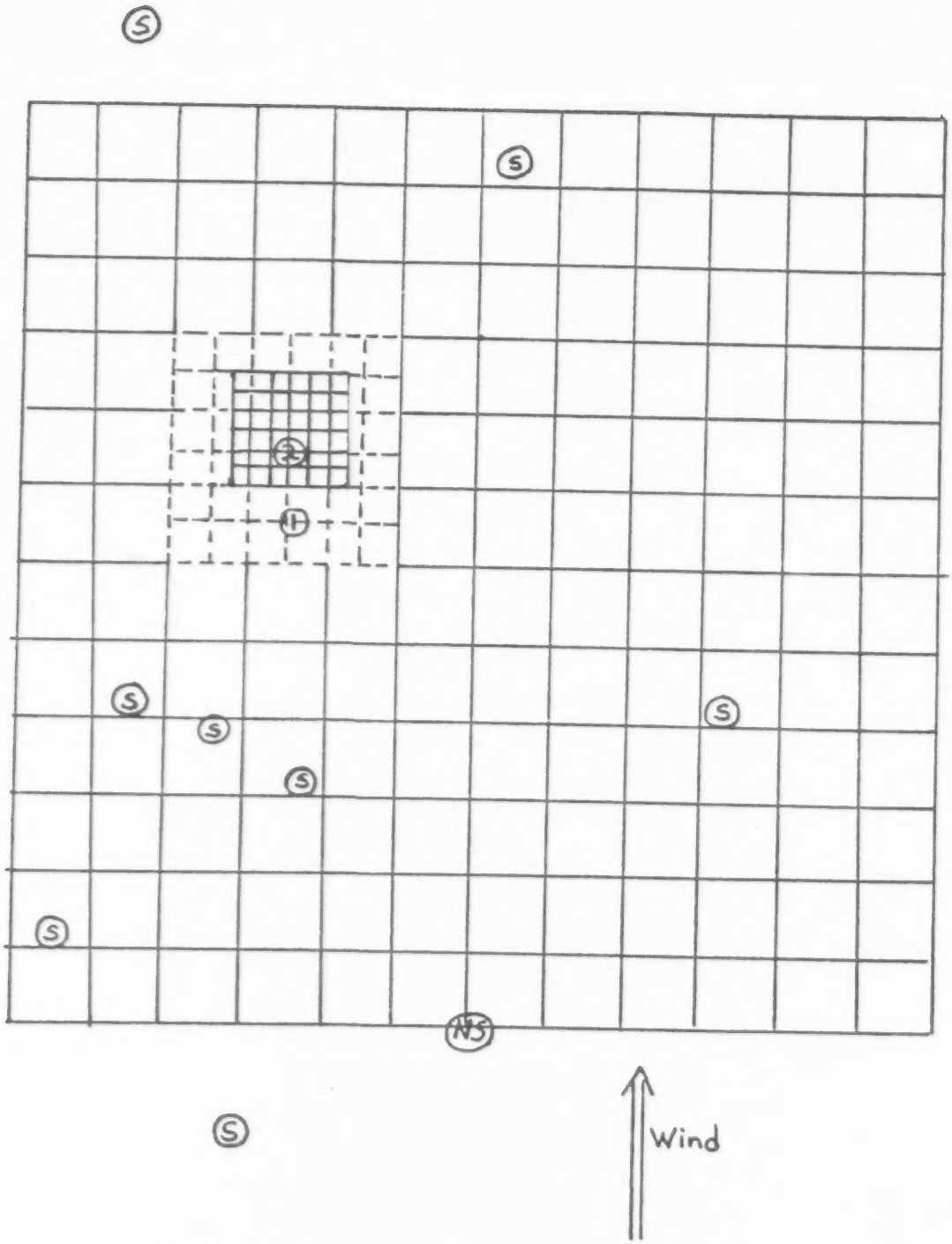
   If H0<-5 w/m2,
   Stable Atmosphere
   Calculate: Ustar, L, H
   If L > 500m, ==> Neutral

   If -5<H0<5 w/m2,
   Neutral Atmosphere
   Calculate: Ustar, H

Output to Models: Ustar, Wstar, L, U10, WD10, T10, Zl, H
time, date

APPLICATION OF REG.308 MODELS TO A MULTISOURCE ENVIRONMENT

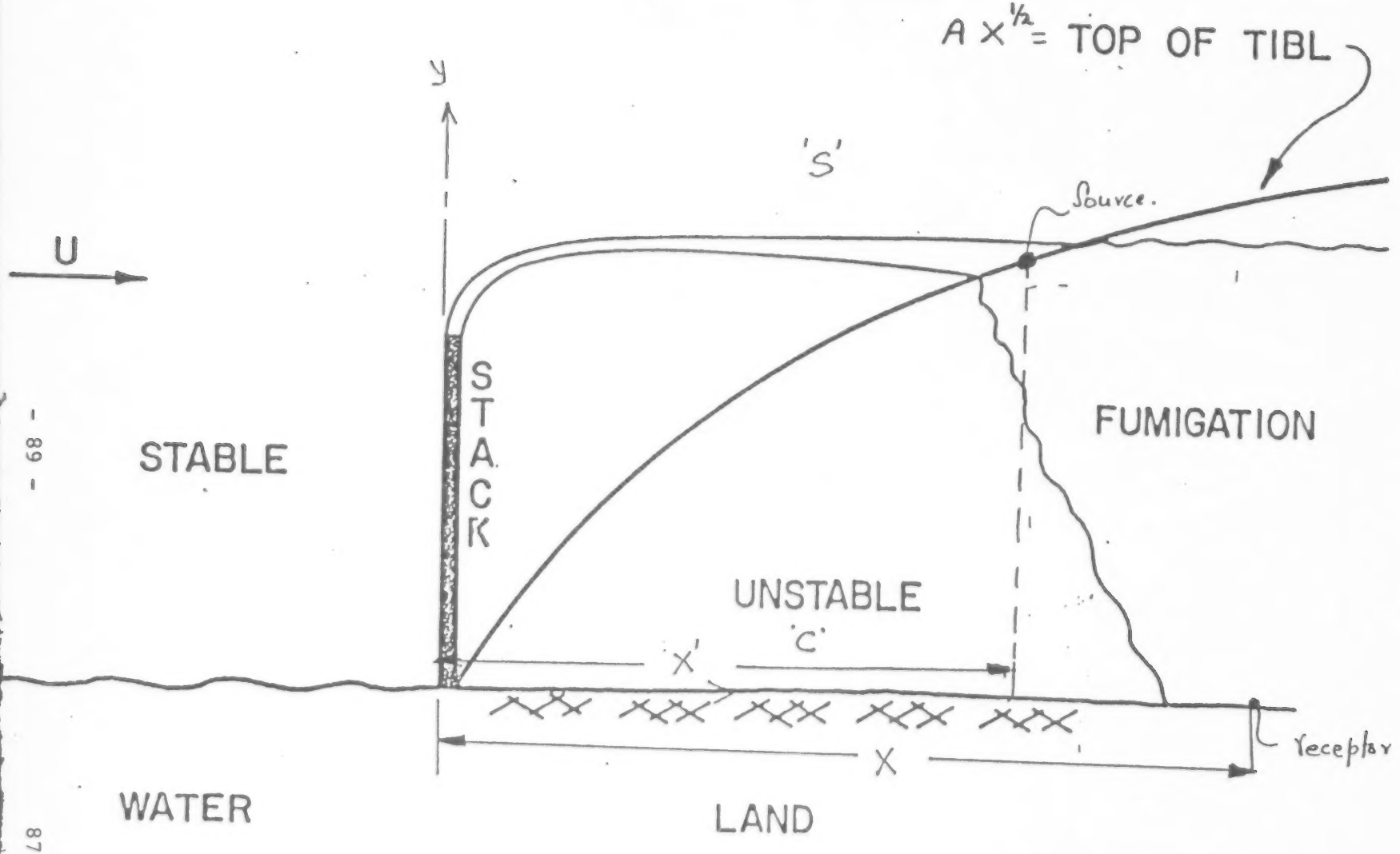
STEP	PROCEDURE
1	Input Model Parameters and Source Data
2	Input Meteorological Data
3	Determine Grid Location
4	Begin Source Loop
5	Calculate Plume Rise
6	Begin Receptor Loop
7	Determine Source-Receptor Distance
8	Calculate Concentration Using Appropriate Dispersion Module
9	End Receptor Loop
10	End Source Loop
11	Sum Source Contributions at Each Receptor
12	Find Location of the Maximum Concentration
13	Set Up Nested Grid (determine new origin and grid spacing)
14	Repeat Steps 4-13 Until Minimum Grid Size Reached or Until Difference Between Successive Maxima Becomes Small
15	Print Results and Save If Concentration Is the Period Maximum
16	Repeat Steps 2-15 For Next Hour Until End of Period
17	Output Period Maximum, Meteorological Parameters and the Percentage Contribution of Each Source to the Maximum



Nested Grid for Gas Model

NS - 'New' Source
S - Source
① - Location of Maximum Concentration for Large Grid
② Location of Maximum Concentration for 2nd Largest Grid

87-240



SHORELINE MODEL

Fig. 1

CPU TIME REQUIRED FOR VARIOUS PROGRAMS FOR THE PROPOSED REGULATION 308

PROGRAM	CPU TIME (MIN) VAX 750
Worst Case Model (per source)	1.00
Worst Case Model with Radius of Influence	2.10
Meteorological Processor (per month)	0.50
Multisource/Grid Maximum Concentration Model for 1 month of data and 10 sources	45.25
Multisource/Grid Maximum Concentration Model looping thru 9 values of A, 10 sources, one hour	85.00

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